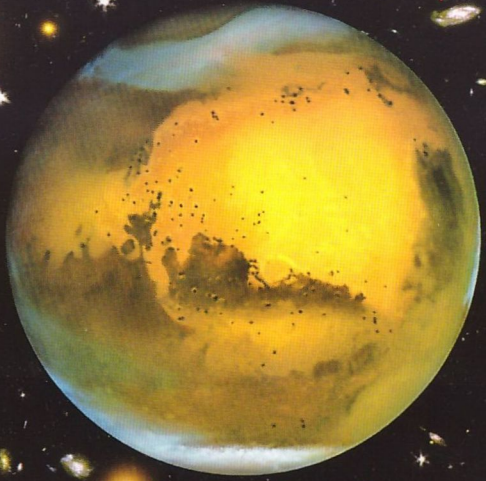
Usborne Fact Cards

Astronomy and space



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Usborne Fact Cards

Astronomy and space

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What are robots doing on Mars?
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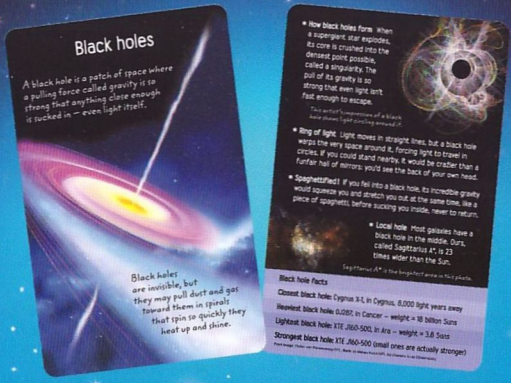

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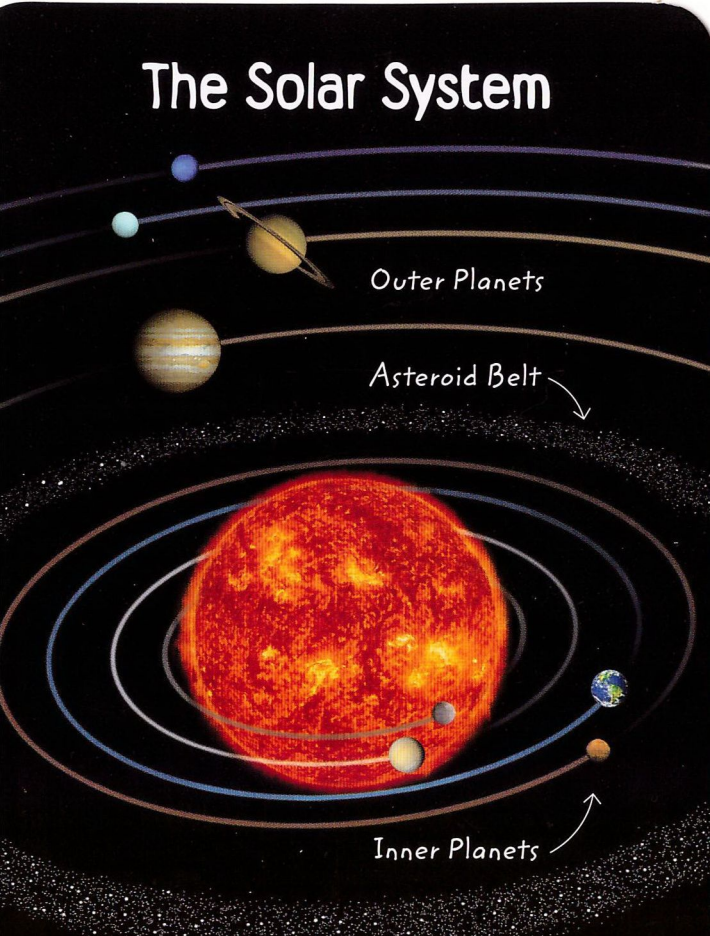
The Solar System



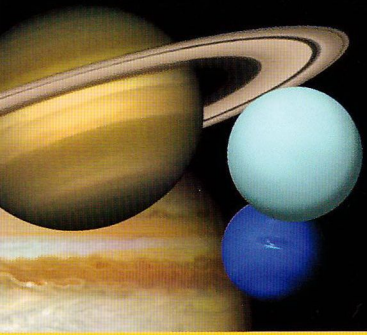
The Solar System is the Sun and all the planets and other natural objects that whirl around it. Its gravity (pulling force) keeps them in their paths.

Note: distances and sizes are not shown to scale

✶ **Big Daddy** Without the Sun, the Earth would never have existed. All the planets in the Solar System were formed out of a saucer-shaped cloud of dust and gas that was pulled into shape by the gravity of the infant Sun.

✶ **Know your planets** To remember the order of the planets in distance from the Sun, try this memory aid: Most (Mercury) Vampires (Venus) Eat (Earth) Moist (Mars) Juicy (Jupiter) Steaks (Saturn) Using (Uranus) Napkins (Neptune).

✶ **Inner planets** The four planets closest to the Sun are called the inner planets. They are made mainly of rock and metal, have few moons and no Saturn-like rings. Earth is an inner planet.



✶ **Outer planets** The four outer planets are also called the gas giants. They are at least ten times heavier than Earth, are made mainly of gas, have many moons, and (often faint) rings.

Solar System facts

Diameter: 15 billion km (9.3 billion miles)

Largest planet: Jupiter

Smallest planet: Mercury

Fastest planet: Mercury

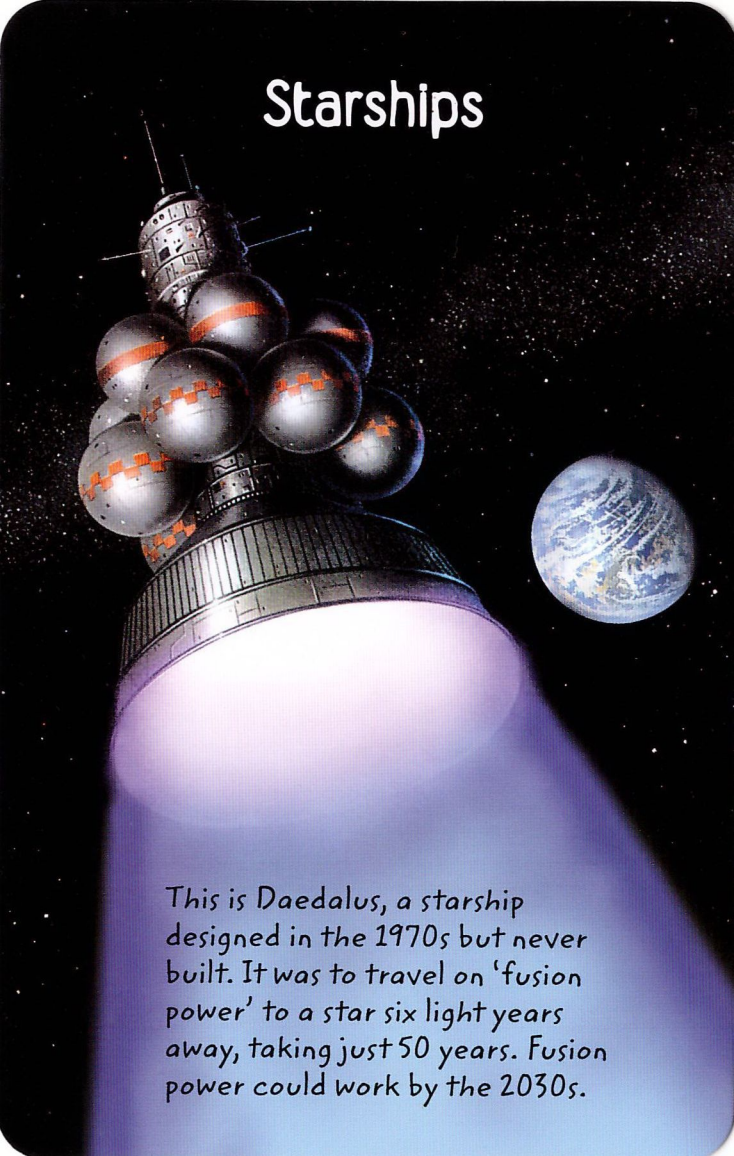
Slowest planet: Neptune

Hottest planet: Venus

Coldest planet: Uranus

Front images: NASA, SOHO (ESA/NASA); **Back**: NASA; **Box cover image**: *Mars* NASA/JPL *Stars* NASA/ESA/S. Beckwith (STScI)/HUDF Team

Starships



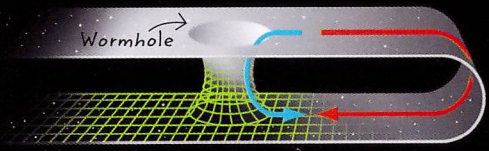
This is Daedalus, a starship designed in the 1970s but never built. It was to travel on 'fusion power' to a star six light years away, taking just 50 years. Fusion power could work by the 2030s.

✶ **Speed limit** Building a starship to travel through space to other stars as fast as light, let alone faster than light (FTL) is impossible. As a ship approached lightspeed, it would get heavier and heavier until it couldn't move at all.

Can we reach the stars?

✶ **Spacetime** The scientist Albert Einstein saw space and time as a kind of sheet, called spacetime, that can be stretched by the gravity of massive objects such as stars. If space is stretchy, it might be squeezed or bent to shorten a long star voyage.

✶ **Wormholes** With a vast amount of energy it may be possible to make a tunnel, known as a wormhole, from one region of spacetime to another. One problem is that you have to be able to reach both ends of the wormhole before you can build it.



A wormhole would be a shortcut through space.

✶ **Warp drive** Another way, in theory, to move vast distances quickly is a warp drive. This could use still-mysterious 'dark energy' to shorten space in front of a starship, and expand it behind. But it would take the energy of the planet Jupiter to run.

Starship scientists

Alan Bond: rocket scientist who led Project Daedalus

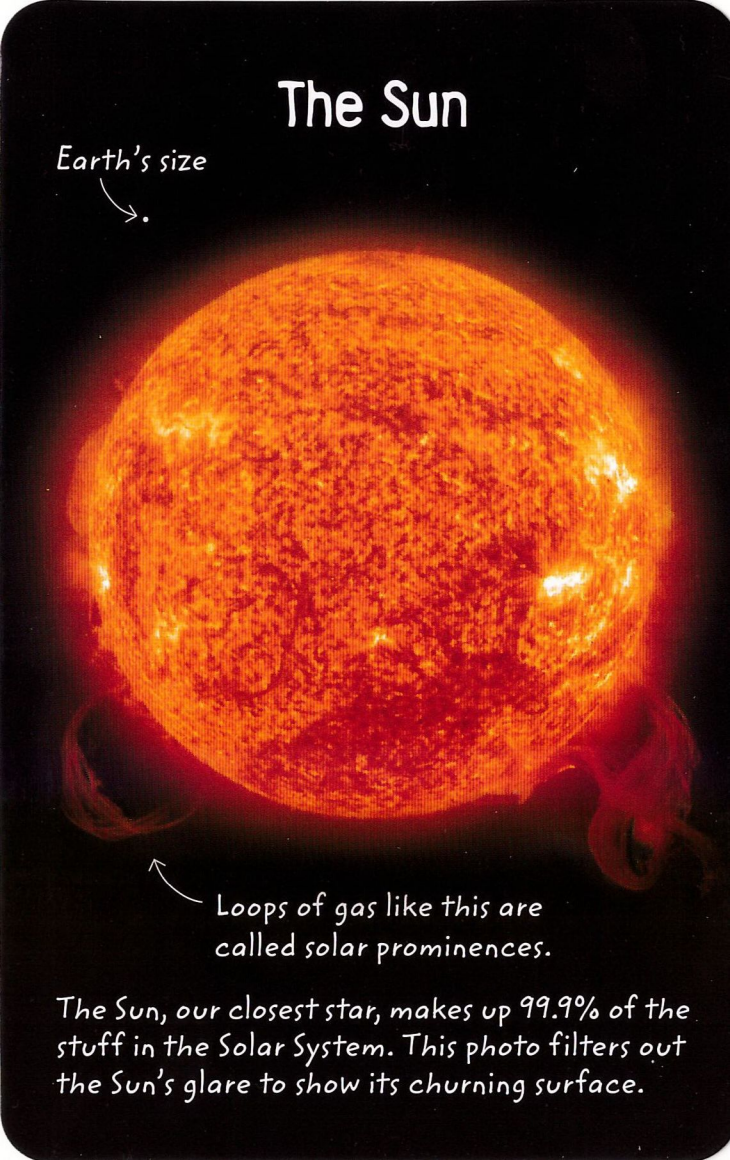
Kip Thorne: studies how wormholes could work

Miguel Alcubierre: thought up the first warp drive theory

Marc Millis: led a NASA project studying new starship ideas

The Sun

Earth's size



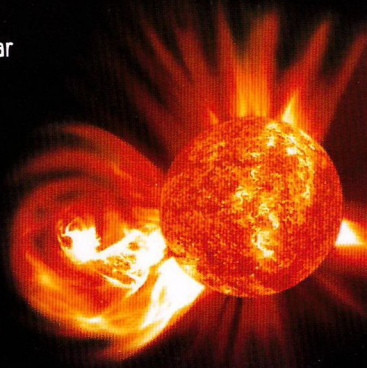
Loops of gas like this are called solar prominences.

The Sun, our closest star, makes up 99.9% of the stuff in the Solar System. This photo filters out the Sun's glare to show its churning surface.

✶ **Seeing the Sun** The Sun is so bright that staring at it can blind you. But you can look at it safely by projecting its image through a pinhole in one sheet of paper onto another. This is one of the best ways to view a solar eclipse (see *Solar sights* card).

✶ **Yellow dwarf** Compared to other stars, our Sun is fairly bright, medium-sized and middle-aged. It is classed as a G2V star, meaning that it is yellowish-white and in the main sequence or dwarf stage of its life.

✶ **Sun storms** Dark spots appear on the Sun before it erupts with powerful outbursts called solar storms, shooting out solar flares of plasma (electrically charged gas) or vast coronal mass ejections.



Coronal mass ejection

✶ **Dark heart** The heart of the Sun is pitch-black. Invisible rays from the Sun's core take ten million years to reach its surface, where they turn into visible light and beam to Earth in eight minutes.

Sun facts

Diameter: 1.4 million km (870,000 miles)

Surface temperature: 5,527 °C (9,981 °F)

Core temperature: 13.6 million °C (24.5 million °F)

Distance from Earth: 150 million km (93 million miles)

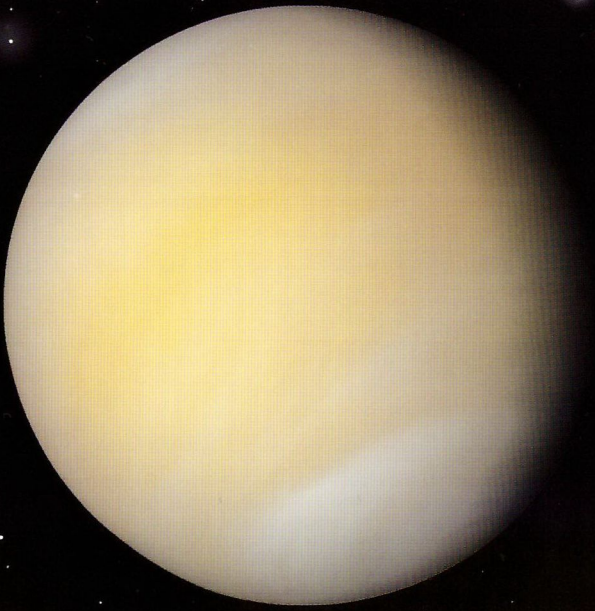
Planets: eight

Adjective: solar

Symbol: ⊙

Images: SOHO (ESA/NASA)

Venus

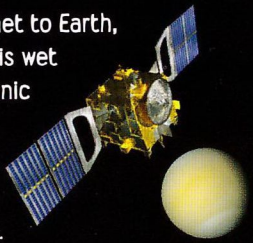


The planet Venus is the brightest light in the sky after the Moon. Its surface is veiled in creamy clouds of carbon dioxide gas.

Order and size of the planets in the Solar System:

✶ **Bright beauty** Venus can only be seen from Earth near sunrise or sunset. The Ancient Greeks thought it was two stars, the Morning and Evening Stars. Later, they named it after their goddess of love, Aphrodite, known to the Romans as Venus.

✶ **Terrible twin** Venus is the nearest planet to Earth, and close in size. But where our world is wet and welcoming, Venus is a hellish volcanic desert with an atmosphere so dense and heavy it could crush a car.



This is the probe Venus Express. In 2006, it discovered lightning on Venus.

✶ **Back spin** Venus spins in the opposite direction to its orbit, so the Sun rises in the west and sets in the east – although you wouldn't see it through the fog. Scientists think that a planet may have crashed into it and knocked it upside down.

✶ **Heavy snowfall** Venus is so hot that heavy metals such as lead turn to gas, then cool and fall on its mountains as metallic snow.

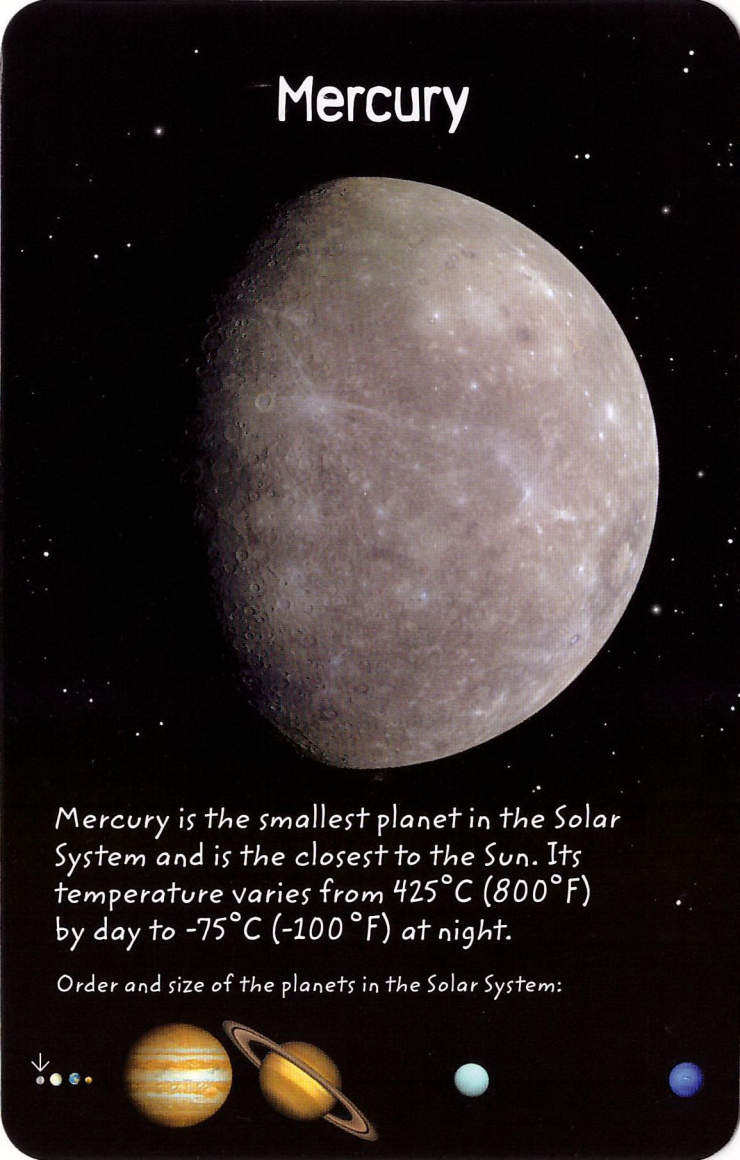
The surface of Venus is strewn with dead volcanoes and shrouded in poisonous fog.

Venus facts	**Moons:** none
Diameter: 12,100km (7,519 miles)	**Gravity:** 91% Earth
Day (dawn to dawn): 116.8 Earth days	**Adjective:** Venusian
Year (one orbit): 224.7 Earth days	**Symbol:** ♀

Distance from Sun: 108 million km (67 million miles)

Front image: Raw data: NASA/JPL, image processing & panorama by Mattias Malmer; **Back**: (t) ESA (b) NASA

Mercury

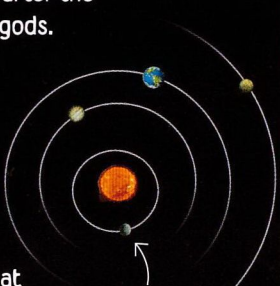


Mercury is the smallest planet in the Solar System and is the closest to the Sun. Its temperature varies from 425°C (800°F) by day to -75°C (-100°F) at night.

Order and size of the planets in the Solar System:

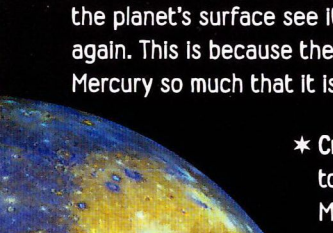
✶ **God of speed** Mercury is the fastest planet, orbiting the Sun in just three months. It is named after the swift-flying messenger of the Roman gods.

✶ **Eccentric** Mercury has the most eccentric (oval) orbit of all the planets. The size the Sun appears in its sky varies from two to three times its size seen from Earth.



✶ **Long days** Mercury turns so slowly that the time from sunrise to sunset takes a whole Mercurian year (one orbit of the Sun).

✶ **Rise again** When Mercury is at its closest to the Sun, parts of the planet's surface see it slowly rise halfway, set, then rise again. This is because the pull of the Sun's gravity speeds up Mercury so much that it is orbiting faster than it's turning.



✶ **Craters** Mercury has no atmosphere to protect it, so it's covered in craters. Most date from four billion years ago when space rocks battered its surface.

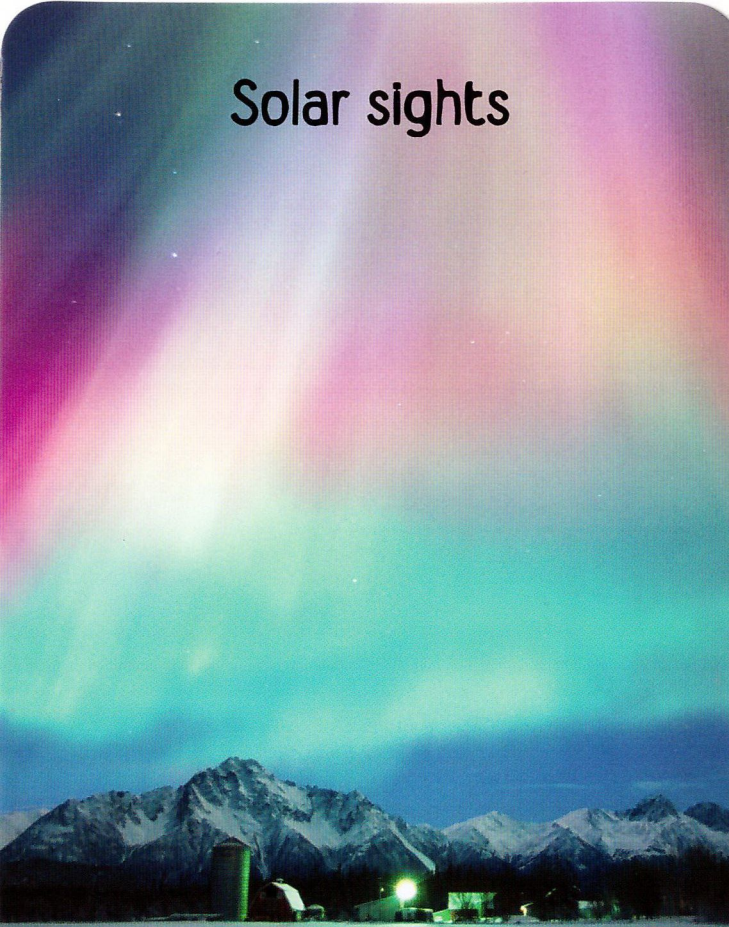
The pale brown area on this photo of Mercury is Caloris Basin, a huge crater.

Mercury facts	**Moons:** none
Diameter: 4,880km (3,032 miles)	**Gravity:** 38% Earth
Day (dawn to dawn): 175.9 Earth days	**Adjective:** Mercurian
Year (one orbit): 88 Earth days	**Symbol:** ☿

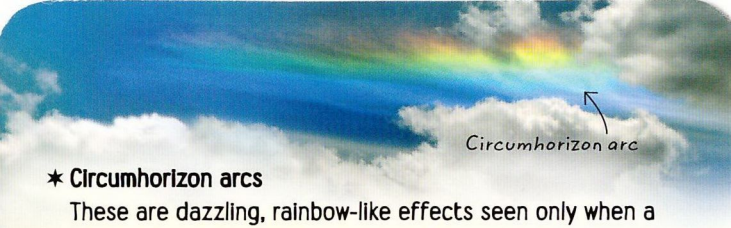
Distance from Sun: 58 million km (36 million miles)

Front image: NASA/MESSENGER/Prockter; **Back**: (b) NASA/MESSENGER

Solar sights



The Aurora Borealis (Northern Lights) is a vivid light show seen in the sky in far northern places. It happens when invisible particles from the Sun hit a magnetic force field around the Earth.



✶ **Circumhorizon arcs**
These are dazzling, rainbow-like effects seen only when a very high summer Sun lights up wispy ice clouds. They are fragments of a giant ice halo (see below) along the horizon.

✶ **Ice haloes** Low sunlight shining through ice clouds can produce a ghostly halo around the Sun, sometimes with bright lights on either side, known as sundogs.

✶ **Daily illusions** When you see the setting Sun touch the horizon, it has already set. Its rays have to go through the atmosphere's light-bending gases before reaching you. They have further to go when the Sun is low in the sky, so they bend more, making it look higher than it is. This also gives us an early sunrise.

✶ **Lights out** A solar eclipse is a rare event when the Moon crosses the Sun's face, hiding its light from us. If the Moon is in the far part of its oval orbit, it looks smaller than the Sun, creating an 'annular eclipse.'

Annular eclipse, or 'ring of fire'

More solar sights

Sun pillar: pillar of light seen above the Sun in icy conditions

Green flash: very rare green light seen above a sunrise or sunset

Glory: circular rainbow-like halo, often around your shadow

Brocken spectre: giant shadow seen in mountain mist, with glory

Front image: Accent Alaska.com/Alamy **Back**: (t) © Jonathan Fox (b) Detlev van Ravenswaay/Science Photo Library

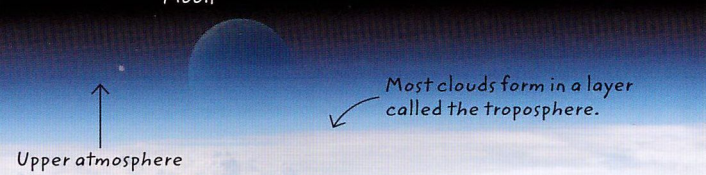
Planet Earth

Earth is a rocky planet, the third from the Sun. Its most striking features are the water that covers 70% of its surface, and the greenery and life which that water makes possible.

Order and size of the planets in the Solar System:

✶ **No place like home** While Mars is frozen, and Venus is boiling, Earth is just the right distance from the Sun to allow plenty of water to exist as a liquid on its surface.

✶ **Good atmosphere** An atmosphere is a layer of gases around a planet. Earth's atmosphere is just 11–17km (7–11 miles) high. 78% is nitrogen gas. 21% is oxygen, which living things need. The rest is moisture and traces of other gases.



✶ **Globe-ish** The Earth is not a perfect sphere, but slightly flattened, so that it measures 42.7km (26.5 miles) more around its equator (east-west) than around its Poles (north-south).

✶ **Hold tight!** Our planet spins at 1,674kph (1,040mph) at its equator, and it orbits the Sun at 108,000kph (67,000mph).

✶ **Seasons** Earth is tilted at an angle of 23.5° as it spins. This means that its regions receive varying amounts of direct sunlight during a year, creating seasons. Venus and Mercury have little or no tilt, so they don't have seasons.

Earth facts	**Moons:** 1
Diameter: 12,742km (7,918 miles)	**Inhabitant:** Earthling, Terran
Day (dawn to dawn): 24 hours	**Adjective:** terrestrial
Year (one orbit): 365.256 days	**Symbol:** ⊕

Distance from Sun: 150 million km (93 million miles)

Front image: NASA's Earth Observatory; **Back:** NASA

The Moon

Size compared to Earth

Earth's only natural satellite, the Moon, is about the size of Australia. It has dark plains called seas or maria, and pale highlands known as terrae. The bright spots are large craters.

✶ **Face to face** The Moon takes the same amount of time to spin around as it does to circle the Earth, so it always has the same side facing us. Its far side has many craters and few seas.

✶ **Phases** As the Moon orbits Earth, one half is always sunlit, but the part we see waxes (grows) and wanes (shrinks) in various phases (stages), seen here as from the northern hemisphere:

New moon | Waxing crescent | First quarter | Waxing gibbous | Full moon | Waning gibbous | Last quarter | Waning crescent

A waning crescent moon over the equator

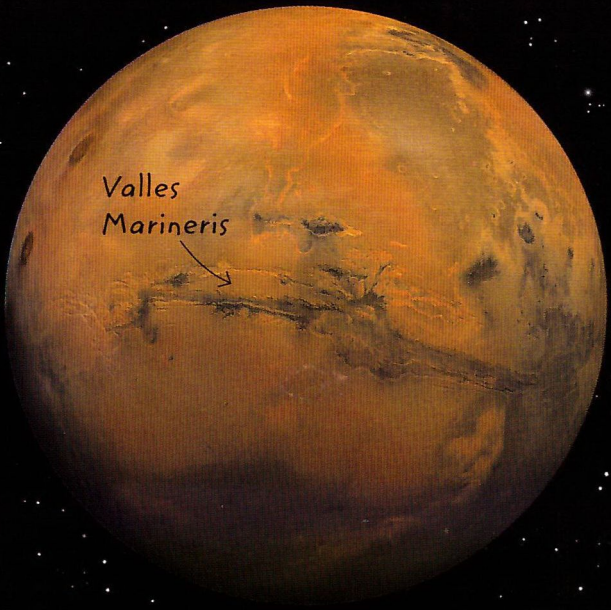
✶ **Upside down?** A northern visitor to the southern hemisphere would see the Moon 'upside down' – and on its side at the equator.

✶ **The Man in the Moon** An old European tradition sees a man's shape in the Moon's dark seas. He carries a bundle of sticks and a lantern, has a small dog, and stands beside a big thorn bush.

Moon facts	
Diameter: 3,474km (2,159 miles)	**Manned missions:** six
Day: 29.5 Earth days	**Gravity:** 17% Earth
Year: 27 Earth days	**Adjective:** lunar
Distance from Earth: 384,403km (238,857 miles)	**Symbol:** ☽

Front image: *Moon* NASA/JPL *Earth* NASA/GSFC SVS; **Back**: (t) NASA/JPL (b) *Moon* NASA/JPL

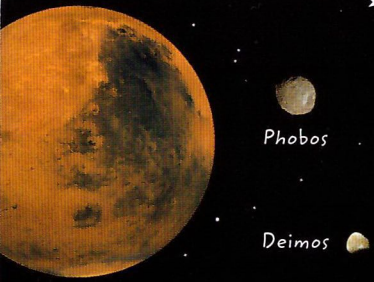
Mars



Mars's huge canyon Valles Marineris is 4,000km (2,500 miles) long, stretching a fifth of the way around the planet.

Order and size of the planets in the Solar System:

✶ **Red planet** Mars was named in ancient times after the Roman god of war. Nicknamed the Red Planet, it is covered with a layer of rusty iron oxide dust and glows orange-red in the sky.



✶ **Fear and Dread** Mars has a rounded moon called Phobos and a smaller, potato-shaped one called Deimos. They were named after the sons of Ares, the Greek god of war. Their names mean Fear and Dread.

✶ **Olympus Mons** Named after Mount Olympus in Greece, this Martian volcano is 27km (17 miles) high: nearly three times as high as Mount Everest.

✶ **Desert views** The surface of Mars has been extensively mapped and photographed by satellites and robot rovers. The image below was taken by NASA's Spirit Rover.

Mars facts	
Diameter: 6,794km (4,222 miles)	**Moons:** two
Day (dawn to dawn): 24 Earth hrs, 42 mins	**Gravity:** 38% Earth
Year (one orbit): 687 Earth days	**Adjective:** Martian
Distance from Sun: 228 million km (142 million miles)	**Symbol:** ♂

Front image: NASA/Viking 1; **Back:** NASA

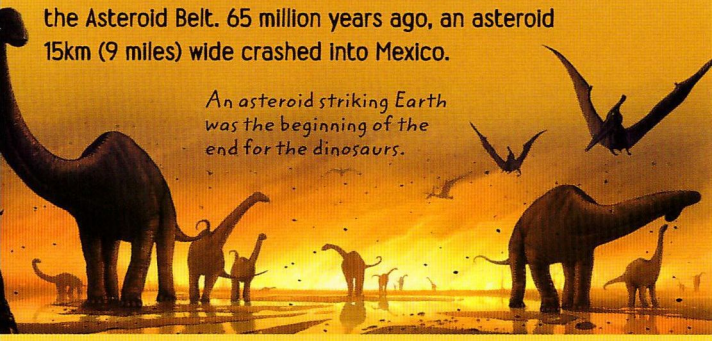

Asteroids
Jupiter
Mars
Asteroids are large space rocks. Millions of them travel around the Sun in a region between Mars and Jupiter called the Asteroid Belt.

✶ **Ceres** About the size of Spain, Ceres is the biggest thing in the Asteroid Belt. It was found in 1801 and classed as a planet. As more and more rocky objects were discovered in the same part of space, it became known as the largest asteroid. In 2006, its status changed again to a dwarf planet.

✶ **Spaced out** You often see spaceships in movies expertly weaving in and out of tightly packed asteroids. In reality, these obstacles are spaced millions of miles apart.

✶ **Name that rock** The first asteroids discovered were named by their finders after mythical goddesses. Now thousands are known, goddesses are running out, and their names even include 2309 Mr. Spock and 9007 James Bond.

✶ **Dino doom** Some asteroids travel closer to Earth than the Asteroid Belt. 65 million years ago, an asteroid 15km (9 miles) wide crashed into Mexico.



An asteroid striking Earth was the beginning of the end for the dinosaurs.

Asteroid facts

Biggest: Vesta, 550km (340 miles) long, 460km (285 miles) wide

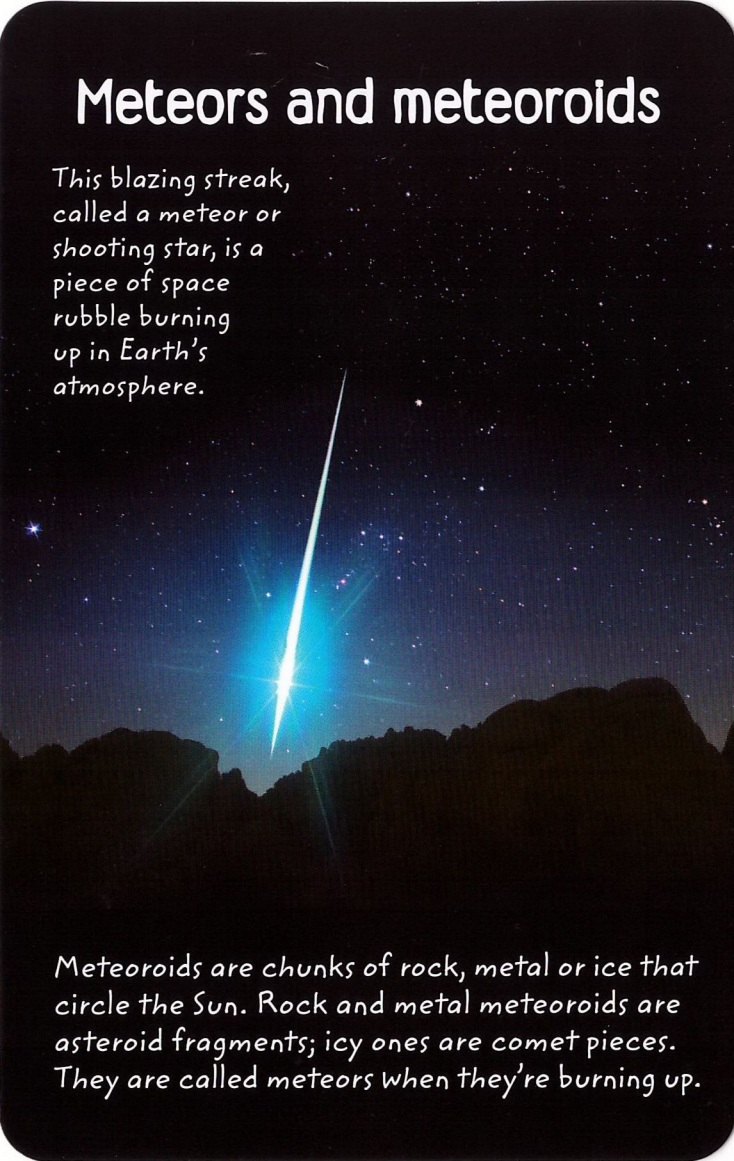
Closest approach to Earth: Toutatis, 900,000km (560,000 miles)

First photographed: Gaspra, 1991, by the space probe Galileo

First found with two moons: Sylvia – Romulus and Remus

Images: Mark Garlick/SPL

Meteors and meteoroids

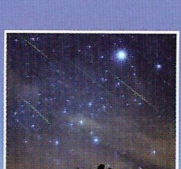


This blazing streak, called a meteor or shooting star, is a piece of space rubble burning up in Earth's atmosphere.

Meteoroids are chunks of rock, metal or ice that circle the Sun. Rock and metal meteoroids are asteroid fragments; icy ones are comet pieces. They are called meteors when they're burning up.

✶ **Meteorites** Most meteors are pea sized and vaporize in seconds, but each year, about 50,000 meteors heavier than 10g (0.4oz) land on the Earth. They are then called meteorites.

✶ **Meteor showers** Most nights, you might see 2–3 meteors an hour, but at times when Earth passes through a cloud of icy meteoroids, the rate soars into a 'meteor shower'. In the Perseid shower in August, up to 75 meteors an hour can be seen.



✶ **Tunguska** At 7:14 a.m. on June 30, 1908, what was probably a meteorite exploded over remote Tunguska in Russia, flattening trees over 2,150km^2 (830 sq miles). Five hours later, the Earth would have turned and it could have hit the city of St. Petersburg.

✶ **Sky watch** The Pan-STARRS telescope in Hawaii uses the world's largest digital camera to scan the skies for Tunguska-style dangers. Every minute, it takes two 1.4 gigapixel photos that, if printed out, would cover a basketball court.

Meteor Crater in Arizona, USA, is 1.2km (3/4 mile) wide. It was made by a large meteorite 50,000 years ago.

Major annual meteor showers

Quadrantid: peaks January 4, comes from constellation Boötes

Perseid: peaks August 12, comes from constellation Perseus

Leonid: peaks November 17, comes from constellation Leo

Geminid: peaks December 13, comes from constellation Gemini

Front image: Walter Pacholka, Astropics/SPL; **Back**: (m) Tony Hallas/Science Faction/Corbis (b) David Parker/SPL

Jupiter

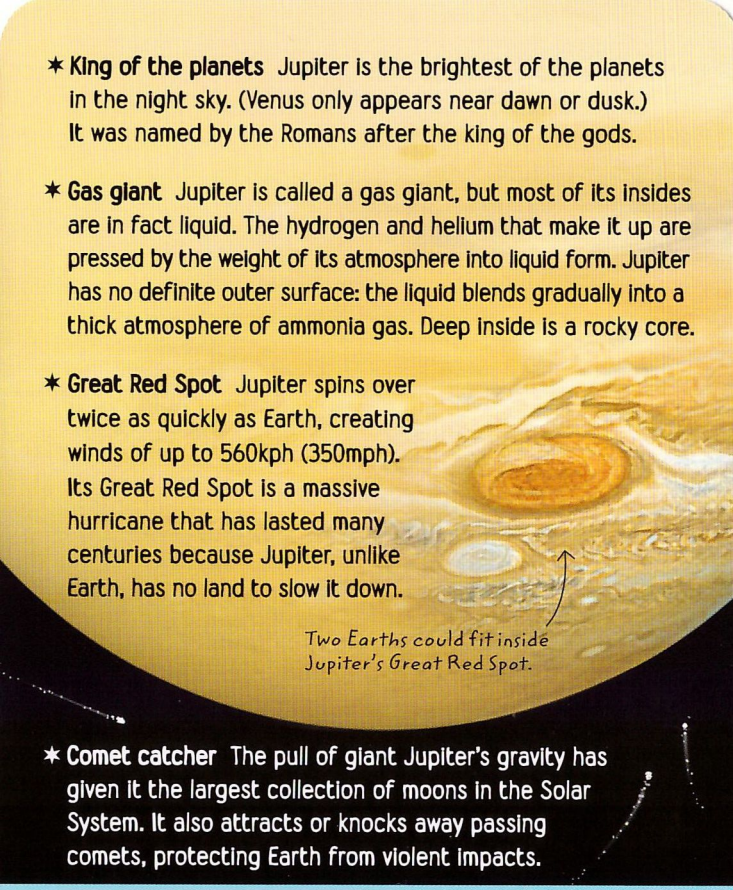
Jupiter is the largest planet in the Solar System, ten times as wide as Earth. Its swirling atmosphere is striped with pale 'zones' and darker 'bands'.

Order and size of the planets in the Solar System:

✶ **King of the planets** Jupiter is the brightest of the planets in the night sky. (Venus only appears near dawn or dusk.) It was named by the Romans after the king of the gods.

✶ **Gas giant** Jupiter is called a gas giant, but most of its insides are in fact liquid. The hydrogen and helium that make it up are pressed by the weight of its atmosphere into liquid form. Jupiter has no definite outer surface: the liquid blends gradually into a thick atmosphere of ammonia gas. Deep inside is a rocky core.

✶ **Great Red Spot** Jupiter spins over twice as quickly as Earth, creating winds of up to 560kph (350mph). Its Great Red Spot is a massive hurricane that has lasted many centuries because Jupiter, unlike Earth, has no land to slow it down.



Two Earths could fit inside Jupiter's Great Red Spot.

✶ **Comet catcher** The pull of giant Jupiter's gravity has given it the largest collection of moons in the Solar System. It also attracts or knocks away passing comets, protecting Earth from violent impacts.

Jupiter facts

Diameter: 142,984km (88,846 miles)

Day (dawn to dawn): 9 Earth hrs, 56 mins

Year (one orbit): 11.9 Earth years

Moons: at least 63

Gravity: 253% Earth

Adjective: Jovian

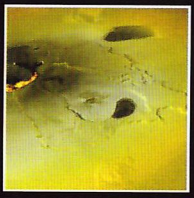
Symbol: ♃

Distance from Sun: 778 million km (483 million miles)

Front image: NASA/JPL/University of Arizona; **Back**: NASA/Voyager 2/PDS/NSSDC/Bjorn Jonsson

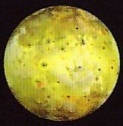
Jupiter's moons

Jupiter has at least 63 moons. The largest four are called the Galilean moons. This photo, taken by the Cassini space probe, shows Io, the third largest, casting a shadow onto its surface.



Lava flowing on Io

★ **Io** Jupiter's gravity pulls at this moon, warping its rocky surface. The friction heats its insides, forming volcanoes that erupt nearly all the time. In 2007, a probe called Galileo saw lava (hot liquid rock) on Io.



Volcanic Io

★ **Ganymede** Larger than Mercury, this is the Solar System's biggest moon. If it orbited the Sun, it would be classed as a planet.

Planet-sized Ganymede

★ **Europa** The surface of this icy moon cracks and refreezes as it is affected by Jupiter's gravity. Beneath may lie deep, salty oceans and perhaps even alien sealife.

Does life lurk in Europa's oceans?

Cratered Callisto

★ **Callisto** Jupiter's second largest moon is too far out to be strongly altered by its gravity. Its surface hasn't changed since it was formed. Callisto still bears the scars of all its meteor strikes, making it the most cratered object in the Solar System.

More facts about Jupiter's moons

Largest: Ganymede, diameter: 5,268km (3,273 miles)

Smallest: S/2003 J 12, diameter 1km (0.6 miles)

Innermost: Metis, distance 128,000km (80,000 miles)

Outermost: S/2003 J 2, distance 30 million km (18.6 million miles)

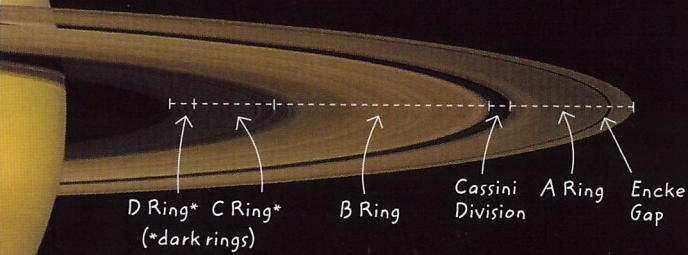
Front image: NASA/JPL/UA; **Back**: (tl) NASA/JPL/Galileo (tr) NASA/JPL/UA (ml) NASA/JPL (mr, bl) NASA/JPL/DLR

Saturn

This is the Solar System's second largest planet. Its rings are made up of pieces of ice, from tiny specks to chunks the size of a small car. These vast rings are, incredibly, just 10m (30ft) thick.

Order and size of the planets in the Solar System:

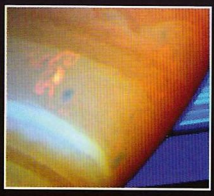
✶ **Ring origins** Saturn's rings may have been created when a big, icy moon tried to form too close to the planet and fell into it, shedding its outer layers on the way. These remains gradually settled into the flat rings we see today.



✶ **Lightweight** The gas giant Saturn is the least dense planet in the Solar System. If a large enough ocean could be found, Saturn would float in it.

✶ **Bulging waistline** Saturn spins so rapidly that it has a slightly flattened shape, bulging out 10% more around its middle.

✶ **Stormy Saturn** Saturn has winds with speeds of up to 1,800kph (1,118mph), and huge lightning storms that last for months.



The 2004 'Dragon Storm' on Saturn had lightning 1,000 times stronger than Earth.

Saturn facts

Diameter: 120,536km (74,898 miles)

Day (dawn to dawn): 10 Earth hrs, 39 mins

Year (one orbit): 29.5 Earth years

Moons: at least 62

Gravity: 91% Earth

Adjective: Saturnian

Symbol: ♄

Distance from Sun: 1,427 million km (887 million miles)

Images: NASA/JPL/Space Science Institute

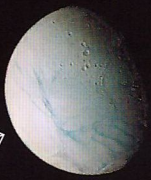
Saturn's moons

Oil and gas are precious fuels on Earth, but on Saturn's largest moon, Titan, liquid gas falls as rain. The Cassini probe has taken pictures of lakes and seas of dark, oily chemicals.

✶ **Titan** The largest moon in the Solar System after Jupiter's Ganymede, Titan is the only place outside Earth known to have liquid lakes and seas. Some scientists say its oily chemicals may be complex enough for simple alien life to have developed there.

✶ **Hyperion** This oddball, burger-shaped moon has so many craters it looks like a sponge. Its shape, along with Saturn and Titan's gravity pulling at it, make it twist and wobble in an unpredictable way.

✶ **Enceladus** This white moon has four 'tiger stripe' cracks near its South Pole. They contain ice fountains which, when they erupt, spray icy particles 100km (60 miles) above the surface.



✶ **Mimas** Nicknamed the Death Star moon because of its likeness to the space station in *Star Wars*, little Mimas has a crater nearly a third of its width.

✶ **Shepherd moons** These little moons orbit between Saturn's rings, or at their edges, 'herding' together the icy chunks that make up the rings, and whipping them into complicated patterns.

Facts about Saturn's moons

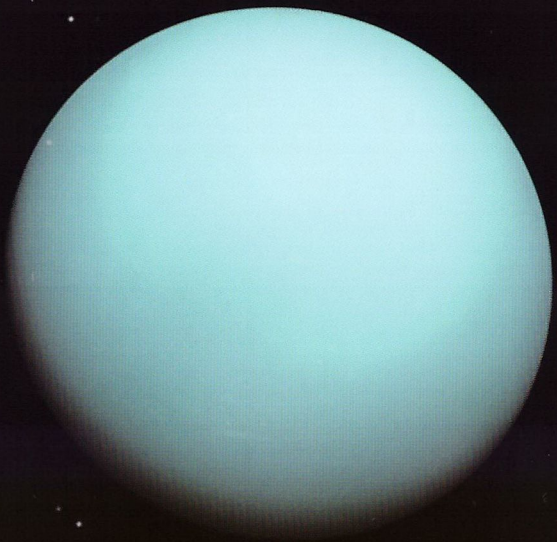
Pan: Saturn's closest moon, orbits in the Encke gap in its 'A Ring'

Iapetus: this two-tone moon is shaped like a walnut shell

Phoebe: orbits 13 million km (8 million miles) away from Saturn

Moonlets: hundreds of mini-moons, just 100m (328ft) wide

Uranus



The pale blue face of Uranus, the third largest planet, comes from clouds of frozen methane. It is named after the Greek god of the sky.

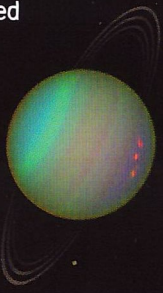
Order and size of the planets in the Solar System:

✶ **George's star** Uranus was the first planet to be found through a telescope, by William Herschel in 1781. At first, he named it *Georgium Sidus* (George's Star) after British King George III, but other astronomers wanted it to be named after a god.

✶ **Rings** Uranus has rings made of frozen methane. They are much fainter than Saturn's, but are visible in the photo below.

✶ **Rolling along** Like Venus, Uranus spins from east to west, but is tilted on its side. It was probably knocked sideways by another planet early in its life.

✶ **Changing seasons** Uranus's steep tilt and long orbit give it highly contrasting seasons that last 21 Earth years. When a probe took a photo of Uranus in 1977, it was in its calm autumn (front of card). A 2003 photo (right) shows late winter clouds and bright storms.



Uranus's largest moons, in shadow. From left to right: Puck, Miranda, Ariel, Umbriel, Titania and Oberon

✶ **Dramatic moons** The moons of Uranus are named after characters from plays and poems by Shakespeare and Alexander Pope.

Uranus facts

Diameter: 51,118km (31,763 miles)

Day (dawn to dawn): 17 Earth hrs, 14 mins

Year (one orbit): 84 Earth years

Moons: 27

Gravity: 89% Earth

Adjective: Uranian

Symbol: ♅

Distance from Sun: 2,871 million km (1,784 million miles)

Front image: NASA/JPL; **Back**: (mr) NASA/ESA/Erich Karkoschka, UA (bl) NASA/JPL (bm) NASA/Ted Stryk

Neptune

The eighth planet from the Sun is Neptune, named after the Roman god of the sea. Its deep blue comes from a methane atmosphere.

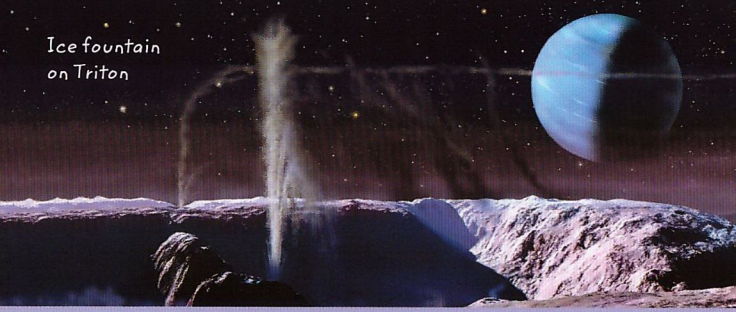
Order and size of the planets in the Solar System:

✶ **High winds** The gas giant Neptune has the fastest winds in the Solar System, reaching speeds of 2,100kph (1,300mph).

✶ **Changing spots** Like Jupiter, Neptune has storms that rage for years. A storm called the Great Dark Spot (see front of card), was photographed by the Voyager 2 probe in 1989. It had gone by 1994, but a new 'Northern' Great Dark Spot soon appeared.

✶ **Triton** Neptune's largest moon, Triton, orbits it in the opposite direction to which the planet spins. Experts think it was once a dwarf planet in the Kuiper Belt, but was pulled in by Neptune's gravity.

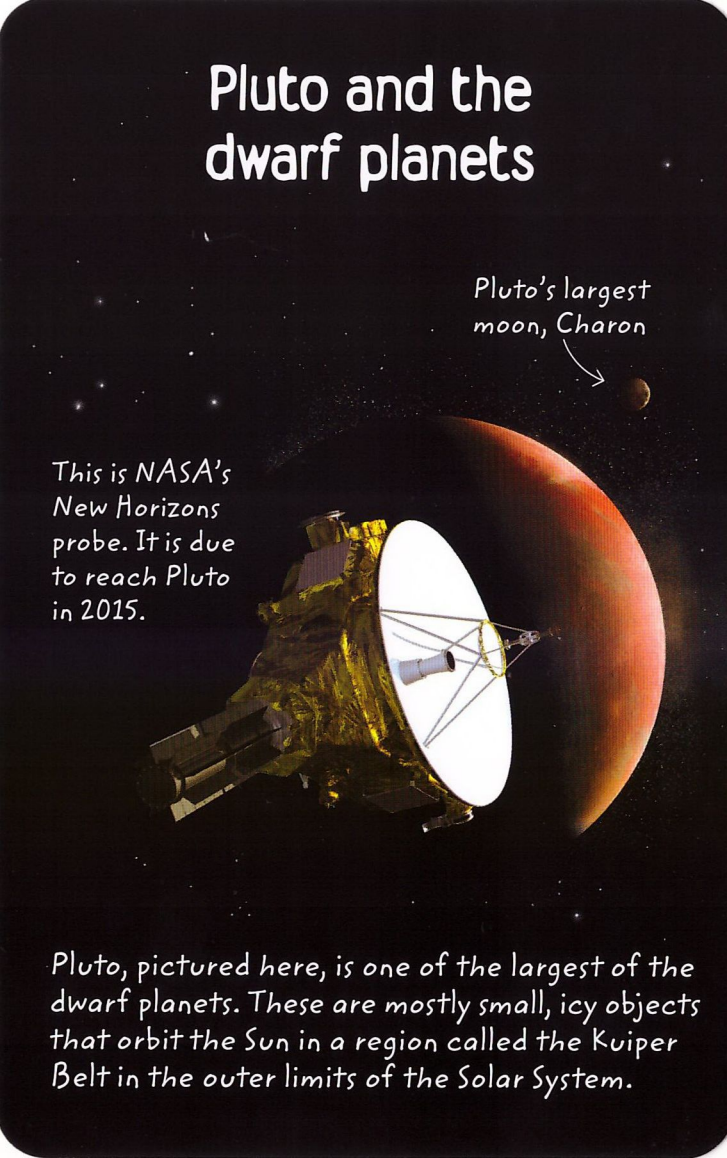
✶ **Ice geysers** Triton is made mainly of frozen nitrogen. Warmth from the distant Sun reaches beneath its surface, melting the ice until it erupts in huge plumes of nitrogen gas.


Ice fountain on Triton

Neptune facts	
Diameter: 49,528km (30,755 miles)	**Moons:** 13
Day (dawn to dawn): 16 Earth hrs, 7 mins	**Gravity:** 114% Earth
Year (one orbit): 165 Earth days	**Adjective:** Neptunian
Distance from Sun: 4,498 million km (2,795 million miles)	**Symbol:** ♆

Front image: NASA/JPL; **Back**: (ml) NASA/JPL/USGS (b) David A. Hardy/SPL

Pluto and the dwarf planets



Pluto, pictured here, is one of the largest of the dwarf planets. These are mostly small, icy objects that orbit the Sun in a region called the Kuiper Belt in the outer limits of the Solar System.

★ **Pluto** Pluto is so far away from the Sun, it takes 248 years to orbit it, and can be as cold as -240°C (-400°F). Found in 1930 by US astronomer Clyde Tombaugh, Pluto was named after the Roman god of the dead, and was known as the ninth planet.

★ **QB1** In 1992, another large object (named QB1) was found in the same area as Pluto, the first of hundreds of such objects now known to orbit in what is called the Kuiper Belt beyond Neptune.

★ **Sedna** This object, discovered in 2003, orbits up to 144 billion km (90 billion miles) away, making it the most distant thing we know of in the Solar System.

★ **Eris** In 2005, an object that may be larger than Pluto was found. It started arguments about what 'planet' means, and was named after Eris, the Greek goddess of conflict.

★ **The dwarfs** In 2006, astronomers decided that space objects such as Pluto and Eris that orbit the Sun, are big enough to be round like a planet, but are also too small to drive most objects out of their orbits should be called dwarf planets.

More dwarf planets (* = to be confirmed)

Makemake: 1,420km (882 miles) wide, named after Polynesian god

Haumea: 1,960km (1,218 miles) long, named after Hawaiian goddess

Ceres: 975km (606 miles) wide, only dwarf planet in Asteroid Belt

***Sedna:** 1,600km (994 miles) wide, named after Inuit sea goddess

Front image: NASA/JHUAPL/SRI; **Back**: NASA/JPL-Caltech

Comets

This is Comet McNaught in 2007. In the southern hemisphere, it was bright enough to see by day.

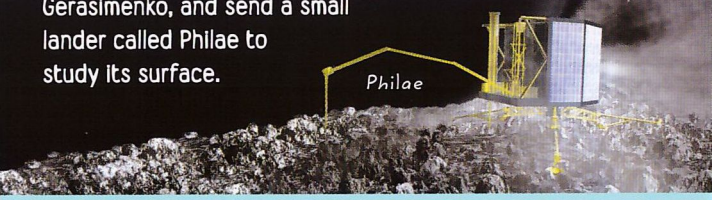
✶ **Hairy stars** Comets are huge lumps of ice, rock and dust that orbit the Sun. If a comet flies close to the Sun, it starts to melt, creating a tail of gas and dust behind it. The Ancient Greeks thought this looked like hair, and named them *kometes*, or 'long-haired stars.'

✶ **Comet crash** In 1996, the comet Shoemaker-Levy 9 broke apart, looking like a string of pearls, before crashing into Jupiter.

Jupiter and Shoemaker-Levy 9

✶ **Halley's Comet** This was the first comet to have its return predicted, by English astronomer Edmond Halley. It passes Earth every 75 years.

✶ **Hitching a ride** In 2014, the Rosetta space probe will intercept Comet 67P/Churyumov-Gerasimenko, and send a small lander called Philae to study its surface.



Comet facts

First recorded: A 'broom star' seen in China, 240BC (Halley's Comet)

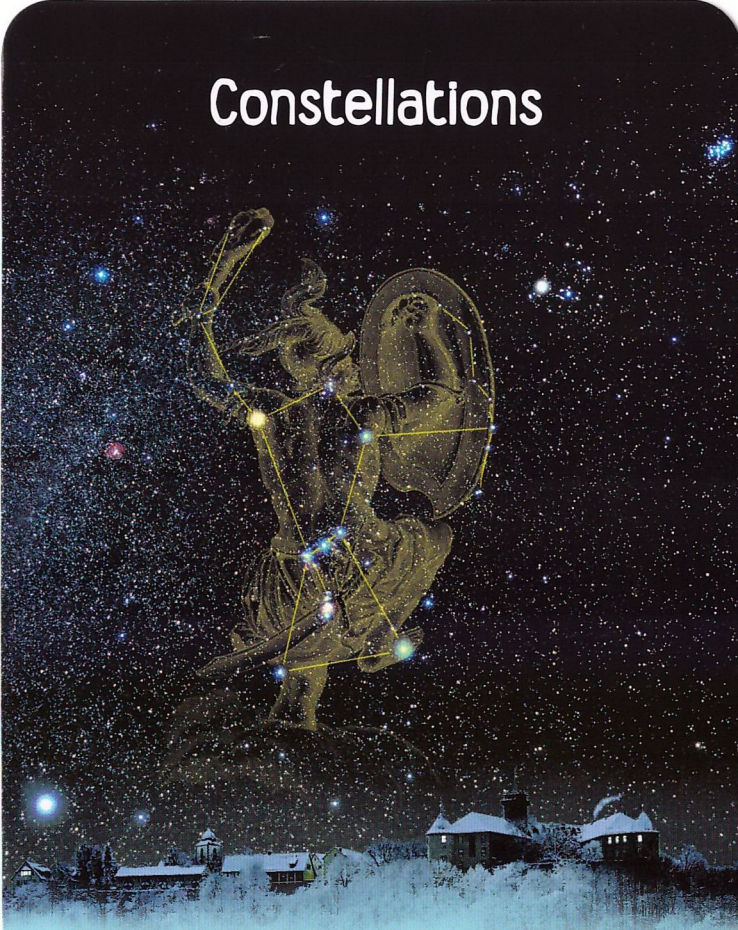
Brightest ever: Great Comet of 1882, visible next to the Sun

Most regular return: Encke's Comet appears every 3.3 years

Longest tail: Comet Hyakutake, 570 million km (360 million miles)

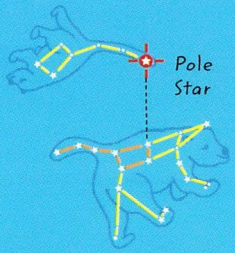
Front image: John White Photos/Alamy; **Back**: (ml) NASA (b) NASA

Constellations



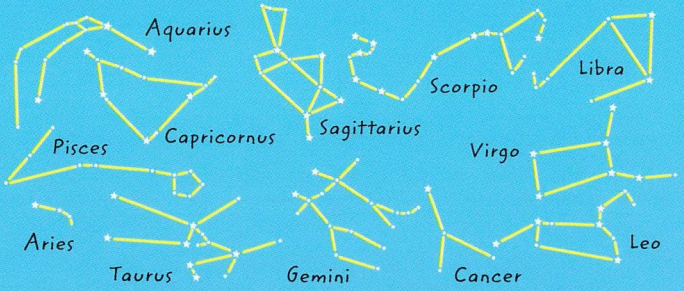
Since ancient times, people have played 'join the dots' with the stars, making up imaginary pictures called constellations. Many are named after mythical figures. This is Orion the Hunter. His belt of three bright stars is easy to spot.

✶ **Star names** Bright stars often have Arabic names, but are also named in Latin after their nearest constellation, with a Greek letter to show their brightness or position. For example, Altair, the brightest star in Aquila, the Eagle, is 'Alpha Aquilae'.



✶ **Polar Bear** The constellation Ursa Major, the Great Bear, contains another pattern (shown in orange) called the Plough or Big Dipper. Two of its stars point to the Pole Star, showing the way north.

✶ **Zodiac** This set of 12 constellations lines the path the Sun and planets seem to follow around the sky each year. At least half of the patterns, such as Leo the Lion, were named as early as 1000BC, in Babylon.



Constellation facts

Brightest: Crux (Southern Cross)

Faintest: Mensa (Table Mountain)

Biggest: Hydra (Water Snake)

Smallest: Crux (Southern Cross)

Named longest ago: Ursa Major

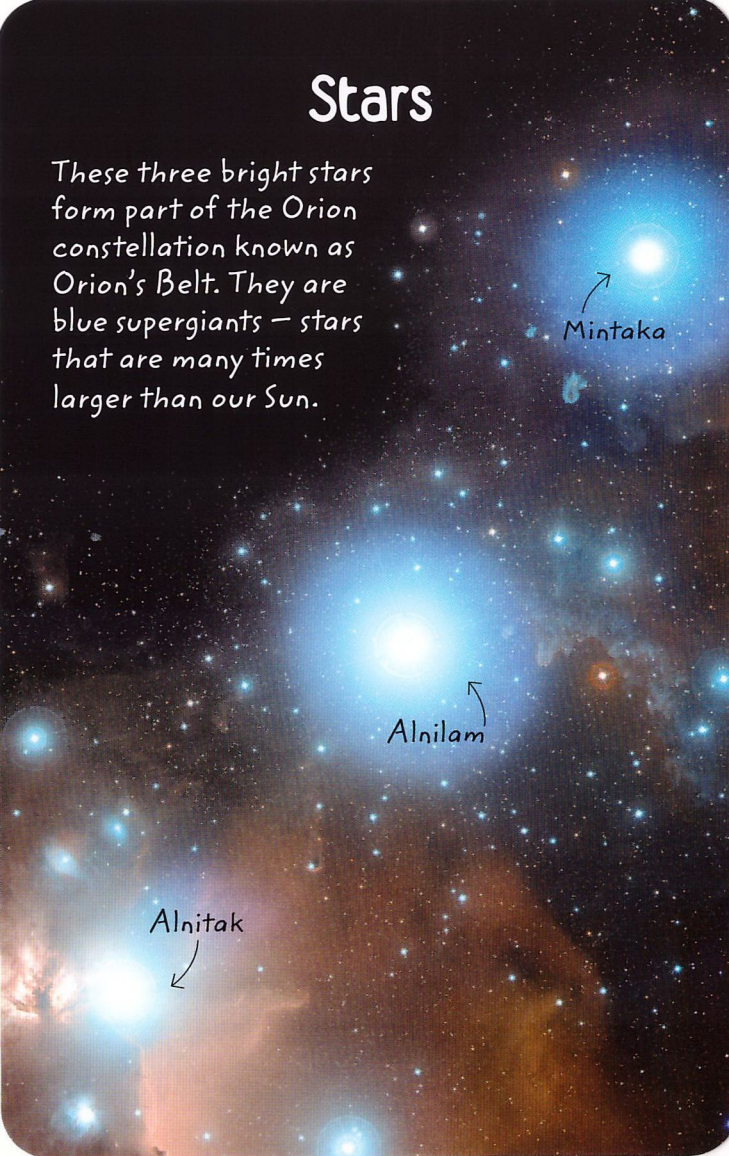
Last to be named: Carina (Keel), Puppis (Poop Deck), Vela (Sail)

Most stars: Centaurus (Centaur)

Fewest stars: Caelum (Chisel)

Front image: Eckhard Slawik/Science Photo Library; Hevelius' Orion artwork by kind permission of USNO/STSI

Stars


These three bright stars form part of the Orion constellation known as Orion's Belt. They are blue supergiants – stars that are many times larger than our Sun.
Mintaka
Alnilam
Alnitak

★ **Why stars shine** A star is a huge ball of super-hot plasma (electrically charged gas). The great temperature and pressure inside it starts nuclear reactions that release energy as light.

★ **Twinkle, twinkle** Stars are so far from Earth that they are just pinpoints. They twinkle because some of the light beaming from them is knocked off course by the churning gases of our atmosphere.

★ **Just next door** The nearest star to the Sun is Proxima Centauri, which is 4.2 light years (40 trillion km or 25 trillion miles) away.

★ **Record breakers** The smallest known star is a 'red dwarf'. Called OGLE-TR-122b, it's slightly larger than Jupiter. The biggest is VY Canis Majoris: a red hypergiant star 2,000 times the size of the Sun.

More star facts

Biggest, viewed from Earth: R Doradus, in Dorado constellation

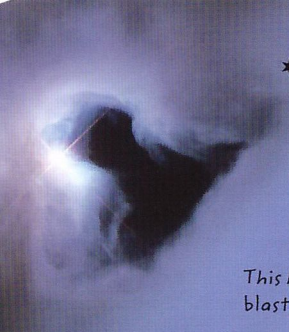
Heaviest: R136a1, in Dorado – 265 times heavier than the Sun

Brightest, viewed from Earth: Sirius, in Canis Major constellation

Brightest of all: R136a1 – 8,700,000 times as bright as the Sun

Life of a star

Stars forming inside these pillars of cloud in the Carina Nebula are firing out energy beams that sculpt the clouds into fantastical shapes.



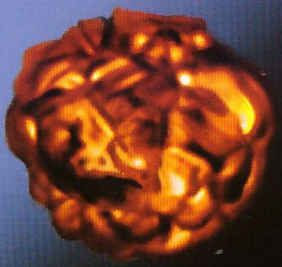
✶ **Protostars** Stars form inside cold, dense clouds of hydrogen gas and dust. At a certain size, a gas cloud collapses under its own weight and heats up to form a cluster of dull, red masses called protostars.

This hot young star, V380 Orionis, has blasted a hole in the cloud around it.

✶ **Starshine** If a protostar reaches 10 million°C (18 million°F), nuclear reactions turn its hydrogen into another gas, called helium, releasing light energy, and a star is born.

✶ **Live fast, die young** 'Dwarf' stars like our Sun can shine for billions of years before they use up their hydrogen fuel. Giant stars are much brighter, but last for only millions of years.

✶ **Swell time** When a dwarf runs out of hydrogen it swells up into a red giant star, while a giant star will balloon into a supergiant.



This is what scientists think a red supergiant may look like close up.

Star life records

Star birthrate: Baby Boom Galaxy in Sextans: 4,000 stars a year

Shortest-lived stars: R136 super star cluster in Tarantula Nebula

Youngest star: IRS-8* in Sagittarius: 3.5 million years old

Oldest star: HE 1523-0901 in Libra: 14.2 billion years old

Front image: NASA/ESA/M. Livio/STScI **Back**: (t) NASA/STScI (b) Dr. Bernd Freytag, CRAL-ENS Lyon

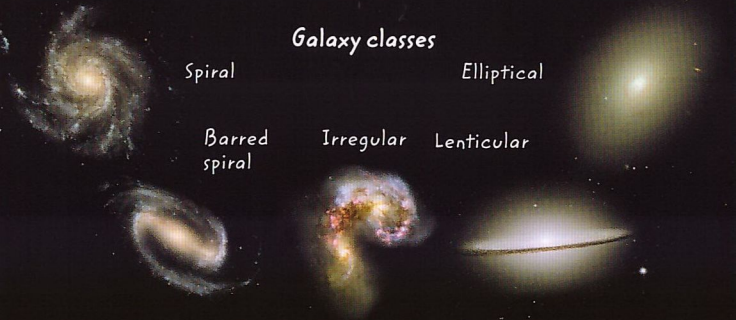
Galaxies

Galaxies are vast groups of stars held together by a pulling force called gravity. This is M81, a large spiral galaxy in the Ursa Major constellation. Even the smallest galaxies have tens of millions of stars.

★ **The Galaxy** For centuries, People thought that our own galaxy, the Milky Way, was the whole universe. It is often just called 'the Galaxy'.

★ **Beyond the Milky Way** In 1925, US astronomer Edwin Hubble proved that swirly star clouds called spiral nebulae were not inside our galaxy, but are really spiral galaxies separate from ours, very far away. The universe was suddenly a lot bigger.

★ **Sorting galaxies** The Hubble Space Telescope has taken pictures of hundreds of thousands of galaxies, which its team then classify by their shape.



★ **Collision course** In 4.5 billion years, Andromeda, the nearest major galaxy, will drift into the Milky Way. It is likely that the two spiral galaxies will merge into one giant elliptical galaxy.

Galaxy facts

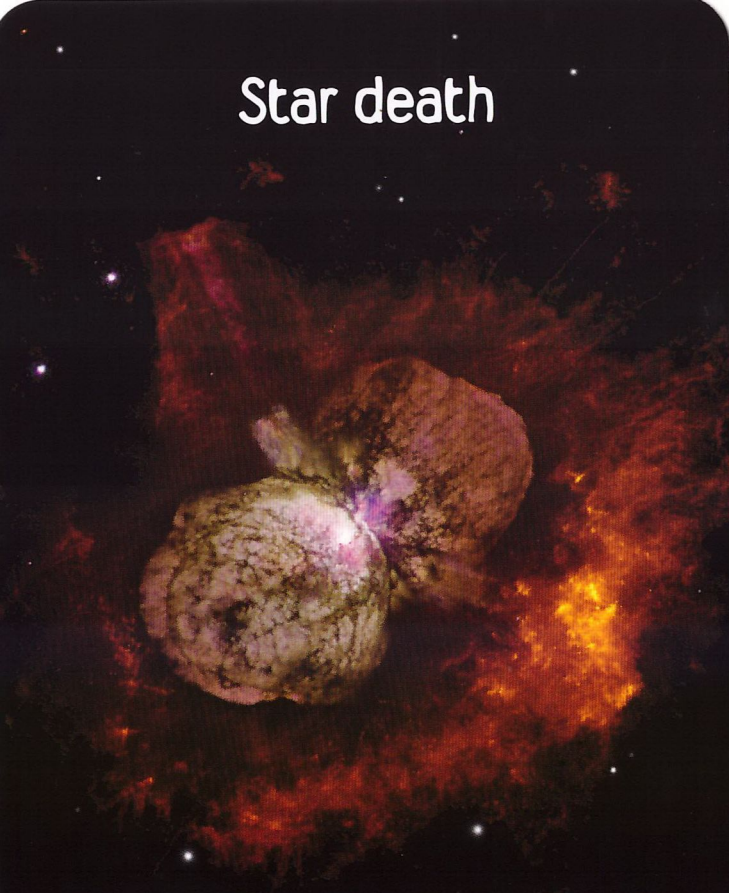
Nearest: Sagittarius dwarf galaxy, 70,000 light years (ly) away

Most distant: UDFy-38135539, in Fornax, 13 billion ly away

Biggest: IC 1101 (Abell 2029 cluster) 5.5 million ly across

Smallest: Willman 1 dwarf galaxy, in Ursa Major, 33 ly across

Star death



This is Eta Carinae. It's a binary star system, in which two or more stars circle each other. The huge dust clouds are signs of its violent, lingering death process, which astronomers have watched for over a century. It could explode at any time.

Eskimo Nebula

★ **Planetary nebulae** As a red giant star dies, it expands so much that its outer layers blow apart, forming a gassy shell called a planetary nebula. (The plural is nebulae.)

★ **White dwarfs** A planetary nebula slowly drifts apart, eventually leaving the dead star's naked core, which is known as a 'white dwarf'. White dwarfs are so dense that one the size of the Earth would be as heavy as the Sun.

Remains of N49 supernova

★ **Supernovae** Supergiant stars end their lives in massive explosions called supernovae. These outshine the whole galaxy, releasing as much energy in one second as our Sun will in its whole lifetime.

★ **Gold explosion** Most chemical elements were first formed by nuclear reactions inside stars. But heavy metals such as gold can only be created in the incredible heat of a supernova: 7,000 times the temperature of the Sun's core.

Star death facts

Nearest white dwarf: Sirius B in Canis Major, 8.6 light years away

Smallest white dwarf: LP-768-500 in Cetus, half the Moon's size

Brightest supernova, from Earth: SN 1006, brighter than Venus

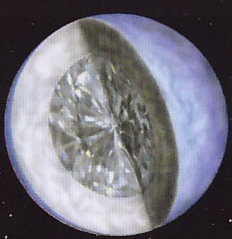
Brightest supernova ever: SN 2005ap, equal to 100 billion Suns

Front image: N. Smith, J. A. Morse (U. Colorado) et al., NASA; **Back**: (t) HST (b) X-ray: NASA/CXC/Caltech/S.Kulkarni et al.; Optical: NASA/STScI/UIUC/Y.H.Chu & R.Williams et al.; IR: NASA/JPL-Caltech/R.Gehrz et al.

Extreme stars

The central glow in this photo, taken by an x-ray space camera, is a spinning star cinder called a pulsar. Its x-rays have lit up nearby gas clouds, which look like a ghostly hand reaching for fire.

✶ **Neutron stars** When a supergiant star explodes, its core crushes in on itself and sometimes turns into a neutron star – a hyper-dense ball that's only about 17km (11 miles) wide. A teaspoon of neutron star-stuff would outweigh New York City.



✶ **Diamond in the sky** BPM 37093 is a white dwarf (the core of a dead giant star) in Centaurus. Scientists think its cool, carbon middle may have crystallized into a diamond 4,000km (2,500 miles) wide.

✶ **Pulsars** In 1967, astronomers found a puzzling star that gave off strangely regular pulses of radiation. It was later classed as a pulsar: a fast-spinning neutron star that flashes like a lighthouse when it faces the Earth.

✶ **Magnetars** This rare type of neutron star is over 50 billion times more magnetic than a scrapyard magnet.

The loops in this picture of a magnetar show its invisible magnetic force field.

More extreme stars

Scorpius X-1: the strongest source of x-rays after the Sun

V838 Monocerotis: ballooned quickly, yet kept its outer layers

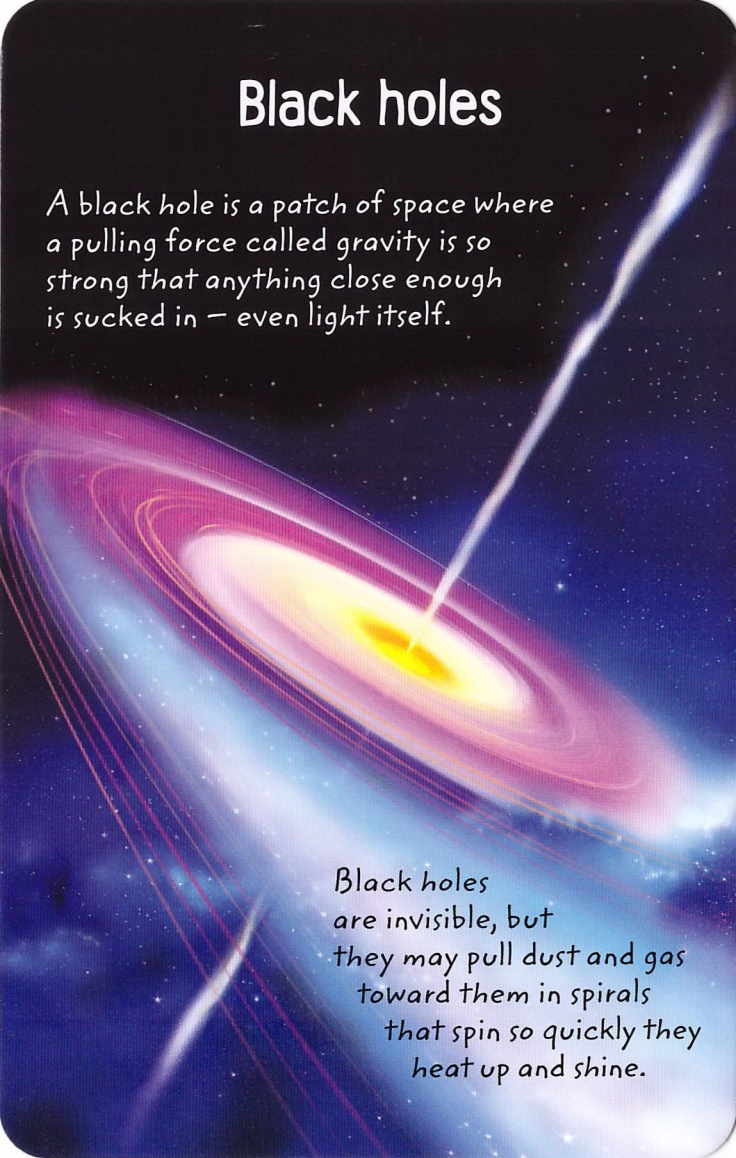
Wolf-Rayet stars: big stars whose matter is rapidly blowing away

Quark stars: exist only in theory; even denser than neutron stars

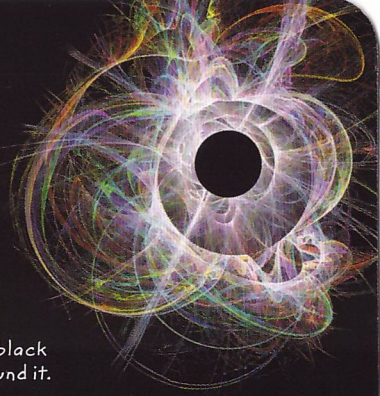
Front image: NASA/CXC/CfA/P. Slane et al.; **Back**: (t) T. Metcalfe & R. Bazinet, Harvard-Smithsonian CfA (b) ESO/L. Calçada

Black holes

A black hole is a patch of space where a pulling force called gravity is so strong that anything close enough is sucked in – even light itself.



Black holes are invisible, but they may pull dust and gas toward them in spirals that spin so quickly they heat up and shine.



✶ **How black holes form** When a supergiant star explodes, its core is crushed into the densest point possible, called a singularity. The pull of its gravity is so strong that even light isn't fast enough to escape.

This artist's impression of a black hole shows light circling around it.

✶ **Ring of light** Light moves in straight lines, but a black hole warps the very space around it, forcing light to travel in circles. If you could stand nearby, it would be crazier than a funfair hall of mirrors: you'd see the back of your own head.

✶ **Spaghettified!** If you fell into a black hole, its incredible gravity would squeeze you and stretch you out at the same time, like a piece of spaghetti, before sucking you inside, never to return.

✶ **Local hole** Most galaxies have a black hole in the middle. Ours, called Sagittarius A*, is 23 times wider than the Sun.

Sagittarius A is the brightest area in this photo.*

Black hole facts

Closest black hole: Cygnus X-1, in Cygnus, 8,000 light years away

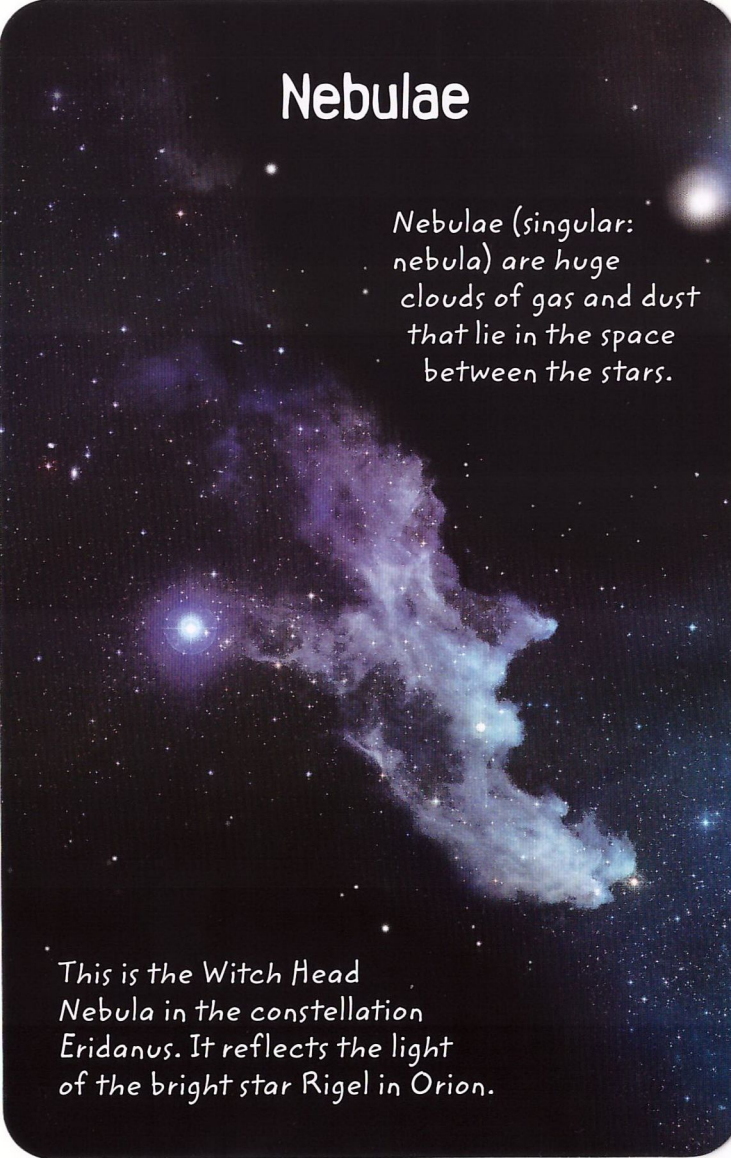
Heaviest black hole: OJ287, in Cancer – weight = 18 billion Suns

Lightest black hole: XTE J160-500, in Ara – weight = 3.8 Suns

Strongest black hole: XTE J160-500 (small ones are actually stronger)

Front image: Detlev van Ravenswaay/SPL; **Back**: (t) Mehau Kulyk/SPL (b) Chandra X-ray Observatory

Nebulae

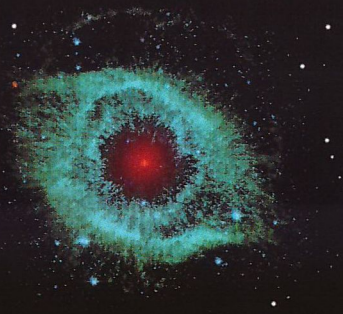


Nebulae (singular: nebula) are huge clouds of gas and dust that lie in the space between the stars.

This is the Witch Head Nebula in the constellation Eridanus. It reflects the light of the bright star Rigel in Orion.

✶ **Orion Nebula** The nearest nebula where new stars are formed is the Orion Nebula, just 1,350 light years away. You can see it without a telescope as the jewel in Orion's sword; it's also known (less romantically) as M42.

✶ **Tarantula Nebula** At 1,000 light years wide, this is the largest nebula yet discovered. It is very distant, but lit up by a bright cluster of huge stars. If it were as near as the Orion Nebula, it would cast shadows on the Earth.



✶ **Helix Nebula** The closest planetary nebula (see Types of nebulae, below) is the Helix Nebula, 700 light years away, in Aquarius.

✶ **Crab Nebula** In 1054, Chinese astronomers saw a 'guest star' so bright it was visible by day for weeks. We now know that it was a vast supernova; the Crab Nebula is its tangled remains.

Types of nebulae

Emission nebula: shines with the light of young stars inside it

Reflection nebula: reflects light from nearby stars

Dark nebula: blocks out stars

Planetary nebula: leftover gas shells of a dead red giant star

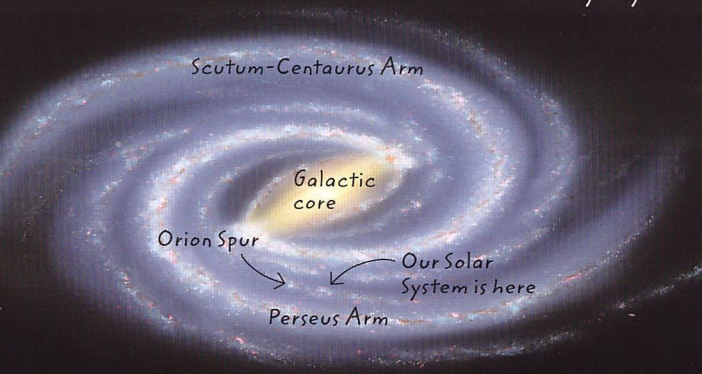
Supernova remnant: leftover gas from a star explosion

Front image: Star Shadows Remote Observatory (Steve Mazlin, Jack Harvey, Rick Gilbert, Teri Smoot, Daniel Verschatse); **Back**: (t) TRAPPIST/E. Jehin/ESO (b) Spitzer Space Telescope

The Milky Way

The pale, cloudy trail of our Milky Way Galaxy is visible on clear nights or from high mountains. This view of it is seen from the top of Mauna Kea in Hawaii. The shapes below are big telescopes.

✶ **Home galaxy** The Milky Way contains about 300 billion stars. It has two main spiral arms and several smaller ones sweeping out from a bar-shaped core. From the side, its shape looks like two fried eggs stuck together.



✶ **Around we go** Just as Earth orbits the Sun, so the Sun and the Milky Way's other stars circle the galactic core at the heart of the Galaxy. Our Sun goes around the Galaxy once every 230 million years, and is on its 20th orbit.

✶ **Bright arms** Spiral galaxies like ours have arms because they have lots of hot, bright, young stars. These don't live long, so by the time they reach the edge of their arm, they've died.

Milky Way facts

Galaxy type: Barred spiral galaxy **Side view:**

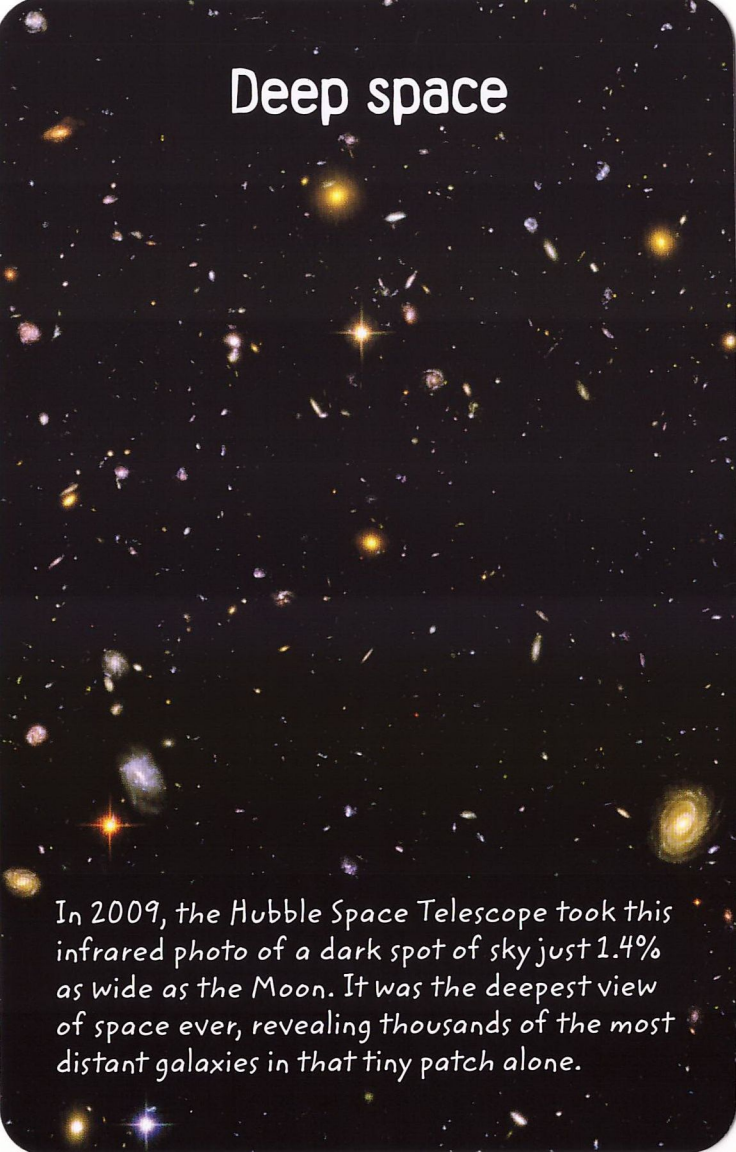
Diameter: 100,000 light years **Age:** 8 billion years

Thickness: (core) 12,000 light years **(arms)** 1,000 light years

Distance from Sun to galactic core: 28,000 light years

Front image: David Nunuk/SPL; **Back**: Nasa/JPL-Caltech

Deep space

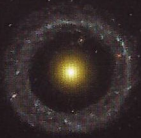


In 2009, the Hubble Space Telescope took this infrared photo of a dark spot of sky just 1.4% as wide as the Moon. It was the deepest view of space ever, revealing thousands of the most distant galaxies in that tiny patch alone.

✶ **A sense of scale** Our Solar System is big: NASA's *New Horizons* probe will take ten years to reach Pluto. But the Galaxy is huge: a similar probe would take half a billion years to reach its middle.

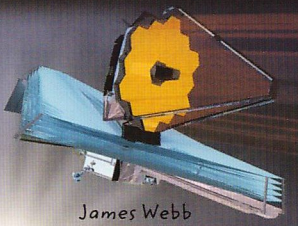
✶ **The Local Group** Our Milky Way has several little galaxies orbiting it, such as the Magellanic Clouds. Together with the nearby Andromeda Galaxy and about sixty much smaller galaxies it's part of a galaxy cluster called the Local Group.

✶ **Supercluster** The Local Group itself is in a cluster of clusters called the Virgo Supercluster. The largest member of the Virgo Supercluster is the Virgo Cluster, which has about 2,000 galaxies.



✶ **Hoag's Object** This unusual, ring-shaped galaxy is 600 million light years away in the constellation Serpens Caput. In the middle are old, yellow stars, surrounded by a circle of hot, young blue stars.

✶ **Time travel** The James Webb Space Telescope is lined up to take over from Hubble. Its ultra-light beryllium mirror will catch rays of infrared light from the most distant galaxies, revealing the early universe.



James Webb Space Telescope

Wonders of deep space

Stephan's Quintet: a group of galaxies crashing into each other

Omega Centauri: a globe-shaped cluster of millions of ancient stars

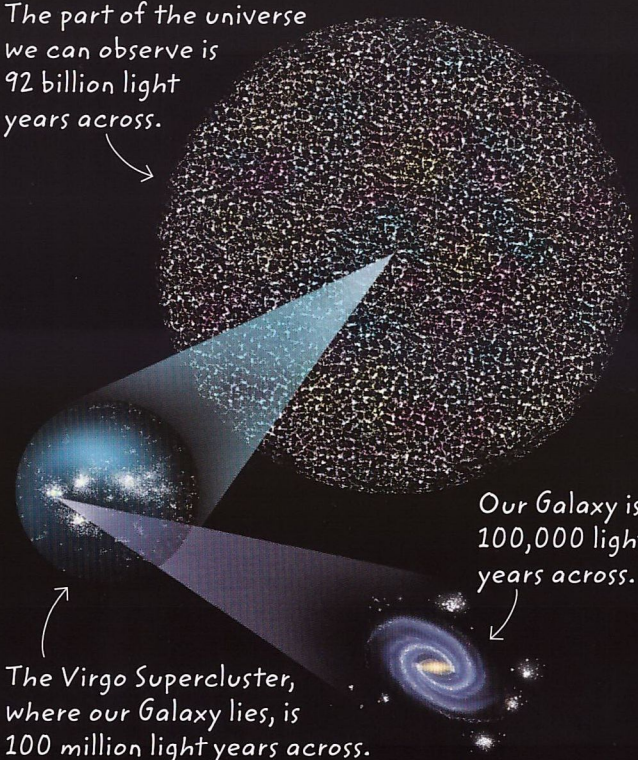
Hanny's Voorwerp: a strange, green, galaxy-sized cloud in Leo Minor

Shapley Supercluster: its huge gravity attracts our own supercluster

Front image: NASA/ESA/S. Beckwith (STScI)/HUDF Team; **Back**: (m) NASA/STScI/AURA (b) NASA

The Universe

The universe is all the matter and energy that exists. It is vast beyond imagining, possibly endless.



★ **To count the stars** To count the number of stars thought to be in the universe, at one star every second, would take 30,000 trillion years: two million times the age of the universe.

★ **Dark mysteries** 96% of the universe is missing. This 'dark' matter and energy can only be detected by its effects. Dark matter's gravity bends space around it. Dark energy is thought to be behind a very strange discovery, made in 1998, that the rate at which space is expanding is actually speeding up.

★ **Size unknown** We can't know how big the universe is because we can never see it all. Light takes time to travel, so there must be stars whose light has yet to reach us. Space itself is expanding faster than light, and faster all the time, so starlight from beyond a certain point can never reach us because it can't catch up.

★ **Multiverse** Scientists think there could be many universes existing side by side, separately, in a 'multiverse'. In each universe, the laws of nature, such as gravity, could work totally differently.

Our universe could be one of many.

Universe facts

Total size: unknown

Average temperature: –271°C (–456°F)

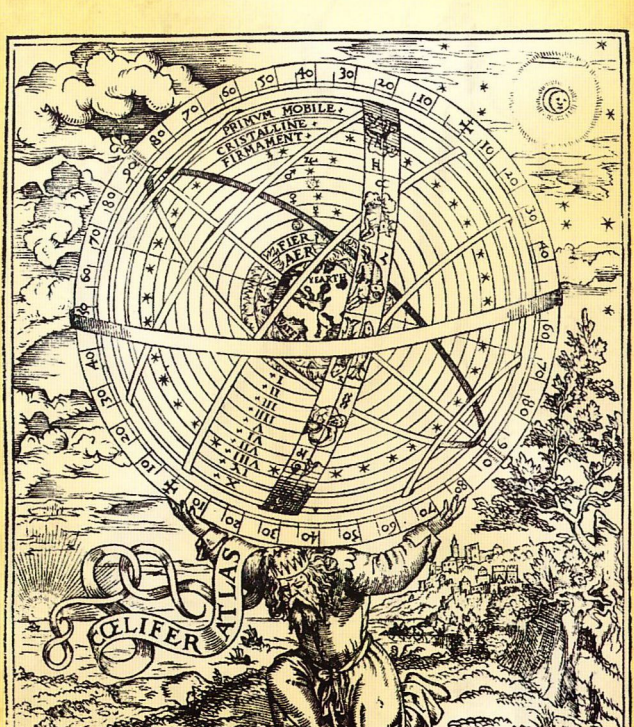
Largest structure: Sloan Great Wall – a tattered ribbon of galaxy superclusters that is 1.37 billion light years long

Galaxies: 500 billion+

Age: 13.7 billion years

Adjective: cosmic

Early astronomy



This picture from 1559 shows how people used to think that stars and planets go around the Earth.

✶ **Sky magic** The science of astronomy was long tied to astrology, the old tradition of finding messages in the stars. From ancient Babylon to 17th century Europe, rulers would often ask astronomers for advice on timing risky ventures such as wars or weddings.

✶ **Hipparchus** This Ancient Greek astronomer pinpointed 850 stars, and calculated the length of a year and the distance of the Moon.

✶ **Star drift** Hipparchus found that the stars creep very slowly east. This is called precession. Today's North Star is Polaris in the constellation Ursa Minor, but in 2000BC, it was Thuban in Draco.

Ptolemy

Hipparchus stargazing in Alexandria, Egypt

✶ **Ptolemy** In 147, Claudius Ptolemy, a Roman-Egyptian astronomer, wrote the *Syntaxis* (or *Almagest*). His book said the planets were set in crystal spheres around the Earth. Ptolemy's view stood for centuries.

More ancient astronomy milestones

3000BC: Newgrange tomb, Ireland, aligned with midwinter sunrise

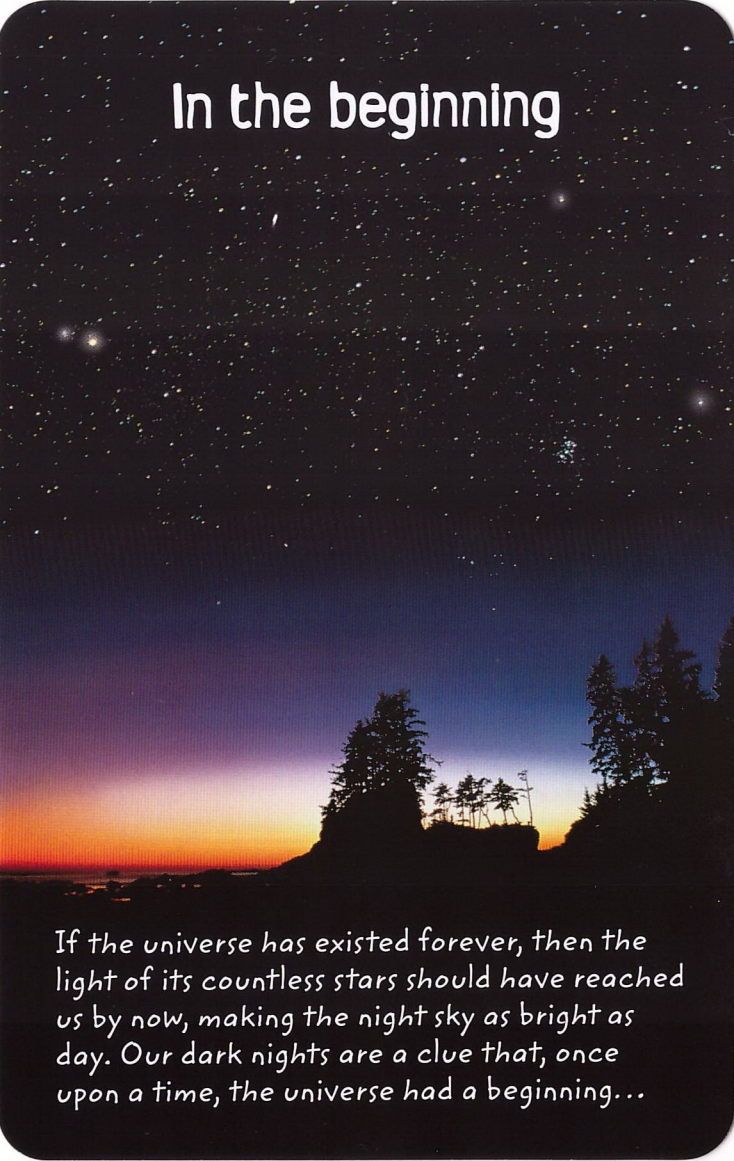
270BC: Aristarchus (Greek) says Earth orbits Sun, but is ignored

200BC: Eratosthenes (Greek) calculates Earth's circumference

499: Aryabhata (Indian) predicts eclipses with great accuracy

Front image: Huntington Library/Superstock **Back**: (tr) North Wind Picture Archives/Alamy (bl) The Granger Collection/Topfoto

In the beginning



If the universe has existed forever, then the light of its countless stars should have reached us by now, making the night sky as bright as day. Our dark nights are a clue that, once upon a time, the universe had a beginning...

✶ **Looking back** Light moves at 300,000km (186,000 miles) per second. But stars are so distant their light takes years to reach us. We only ever see stars as they were when their light left them. A light year is how far light travels in a year. When we see stars billions of light years away, we are glimpsing the early universe.

✶ **Flying apart?** In 1929, US astronomer Edwin Hubble found that all galaxies seem to be moving away from each other, and the more distant they are, the faster they seem to move. This is an illusion caused by the space between the galaxies expanding.

✶ **Big bang theory** This is the idea that if space has expanded, then the universe must once have been much denser and hotter. At the Big Bang, it expanded incredibly quickly and began to cool down.

The space between the galaxies is still expanding.

✶ **Wow!** 13.7 billion years ago, the part of the universe we can now see was packed in a space tinier than an atom. Then, in a fraction of a second, it expanded trillions of times, to the size of a beachball. A second after the 'Bang' it was 1 trillion km (600 billion miles) wide.

The early universe: scientific milestones

1927: Belgian priest Georges Lemaître shares his Big Bang Theory

1929: US astronomer Edwin Hubble shows universe is still expanding

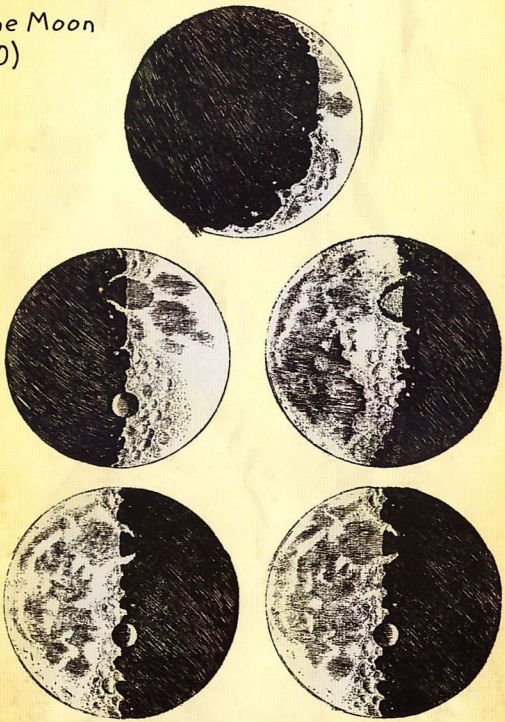
1981: US astronomer Alan Guth says early universe grew rapidly

2003: NASA's WMAP probe shows universe is 13.7 billion years old

Front image: David Nunuk/SPL; **Back**: Chris Butler/SPL

Famous astronomers

Galileo's sketches of the Moon (1610)



Italian astronomer Galileo Galilei was the first person to see the skies through a telescope. He was startled to discover that the Moon has mountains, and that Jupiter has moons of its own.

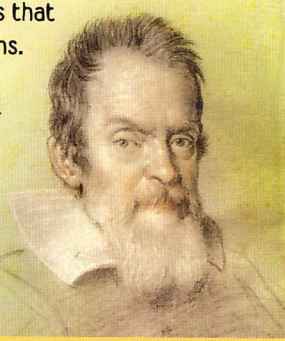
✶ **Copernicus** In 1543, Nicolaus Copernicus, a Polish astronomer, argued that the planets, including Earth, circle the Sun. This contradicted the views of most other astronomers, as well as Church teaching, and people didn't accept it for a long time.

✶ **Tycho** A Danish astronomer named Tycho Brahe made better observations of the stars than anyone before. A feisty fellow, he once lost his nose in a swordfight and made himself a new one out of metal.

Tycho Brahe
(1546–1601)

✶ **Kepler** After Tycho died, German astronomer Johannes Kepler used his findings to calculate the laws of planetary motion. His first law, for example, says that the planets orbit the Sun on oval paths.

✶ **Galileo** Galileo's biggest find was that the planet Venus has phases, like the Moon. This hinted that it orbits the Sun, making Copernicus right. But the Pope disagreed, and put Galileo under house arrest.



Galileo Galilei
(1564–1642)

More famous astronomers

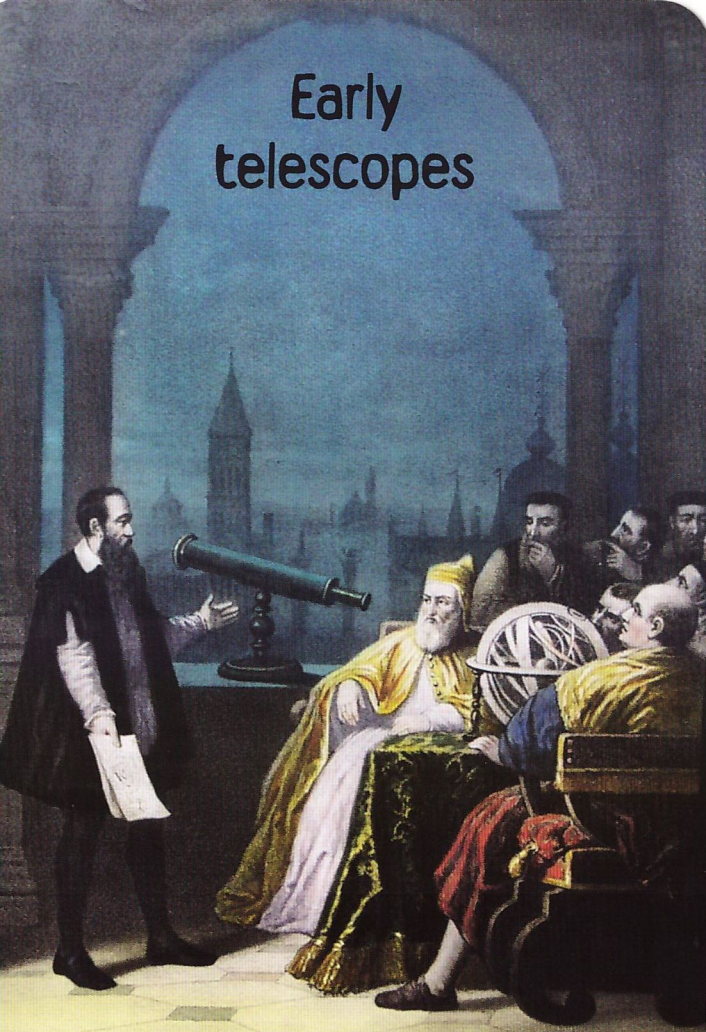
Abd al-Rahman al-Sufi: 965, Persia, saw the Large Magellanic Cloud

Christiaan Huygens: 1655, Netherlands, discovered Saturn's rings

Charles Messier: 1774, France, made a list of 'deep sky objects'

Edwin Hubble: 1925, USA, proved galaxies are outside the Milky Way

Early telescopes



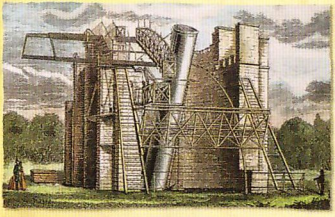
Galileo Galilei showing his new telescope to the Doge (ruler) of Venice – the man in the hat.

✶ **First telescope** The telescope was invented by a Dutch spectacle maker named Hans Lippershey in 1608.

✶ **Galileo** Italian scientist Galileo Galilei improved Lippershey's invention and used it to study the stars. The word 'telescope' (meaning 'far-viewer') was first used at a party held for Galileo.

Hans Lippershey (1570–1619)

✶ **Newton's reflector** The glass lenses of Galileo-style 'refractor' telescopes are heavy, hard to make, and images seen through them have rainbow rings around them. In 1688, Isaac Newton invented a 'reflector' telescope that used curved mirrors instead, giving much clearer images.



Rosse's telescope at Birr Castle

✶ **Leviathan** In 1845, the Irish Earl of Rosse built a telescope with a mirror 1.8m (6ft) wide, known as the Leviathan of Parsonstown. He used it to discover the spiral shape of what we now know to be far-off galaxies.

More telescope milestones

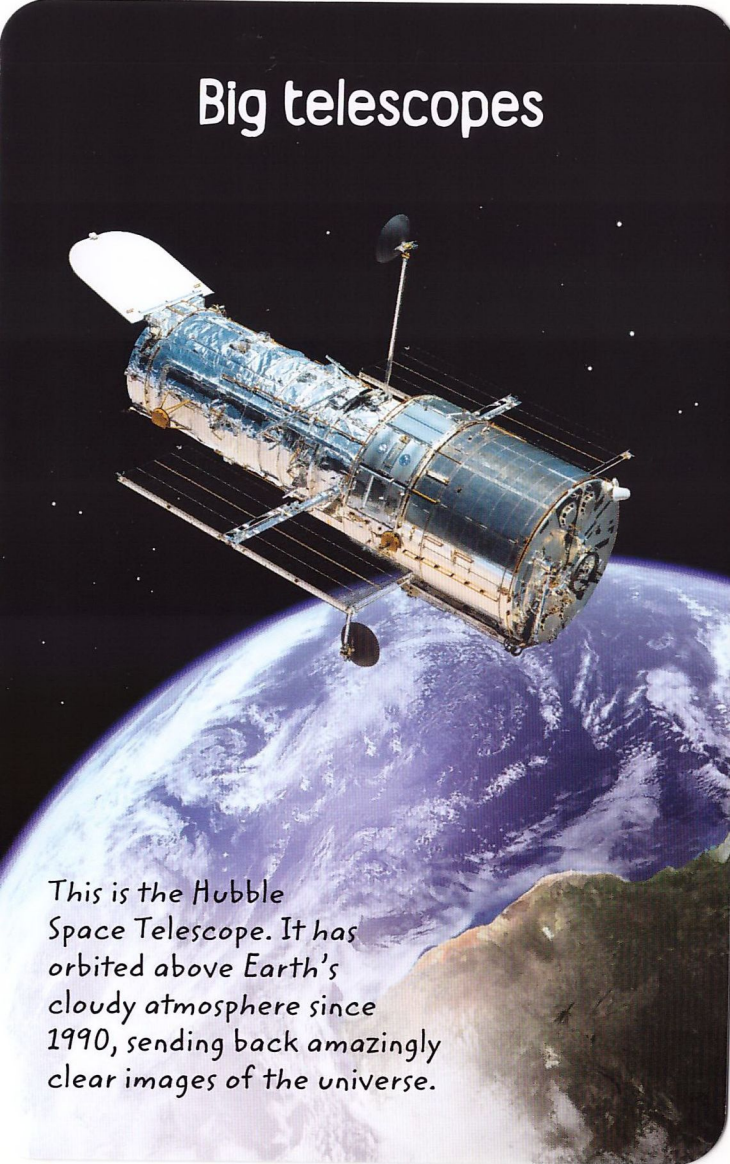
1000: Arab scientist Ibn al-Haytham shows how lenses work

1611: Johannes Kepler designs an outward-curving eyepiece lens

1675: Christiaan Huygens invents the multi-lens eyepiece

1729: Chester Moore Hall invents a lens without rainbow rings

Big telescopes



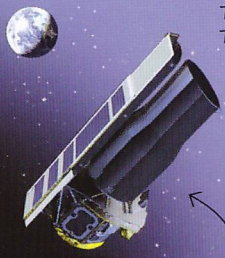
This is the Hubble Space Telescope. It has orbited above Earth's cloudy atmosphere since 1990, sending back amazingly clear images of the universe.

✶ **Bigger is better** Telescopes with huge mirrors or dishes are needed to detect the dim glow of the furthest stars.

✶ **Radio scope** Arecibo Radio Observatory in Puerto Rico detects pulses of energy called radio waves from space and uses them to make pictures. It picks them up on a dish 305m (1,000ft) wide.

✶ **Laser vision** Earth's atmosphere blurs the stars, but the Very Large Telescope in Chile measures the blurring by firing a precisely aimed laser into the sky. Its flexible mirror then makes lots of adjustments to improve the view.

The Very Large Telescope



✶ **Space telescopes** Space telescopes can detect types of light that we cannot, helping them to photograph very faint objects. The Spitzer Space Telescope has found new planets using infrared light.

Spitzer Space Telescope

Optical telescopes with the largest mirrors

Single mirror: Gran Telescopio Canarias, Spain – 10.4m (34ft)

Combined mirrors: Large Binocular Telescope, USA – 11.8m (39ft)

Combined telescopes: Keck I and II, Hawaii, USA – 10m (33ft)

Future: European Extremely Large Telescope, Chile – 42m (138ft)

Front image: NASA/HST; **Back**: (t) ESO/Y. Beletsky (b) NASA/JPL-Caltech/R. Hurt (SSC)

Planet hunting

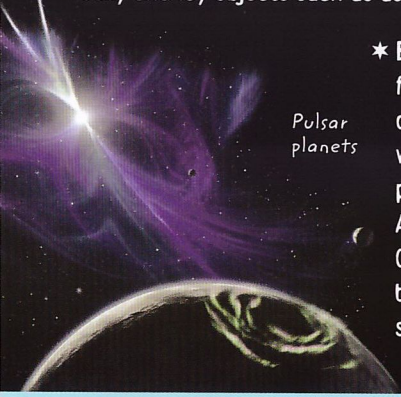
Kepler combines 42 super-sensitive digital camera pictures to scan each patch of space.

This is NASA's Kepler Space Telescope. Since its launch in 2009, it has discovered over a dozen new planets outside our Solar System.

✶ **Wandering stars** The Ancient Greeks saw Mercury, Venus, Mars, Jupiter and Saturn as five stars. These moved around (unlike the other stars) so the Greeks called them *planetes* ('wanderers'), giving us our word planet.

✶ **Seven heavens** Until the 1600s, the Sun, Moon and planets were thought to be fixed in 'seven heavens' – revolving, hollow crystal balls surrounding the Earth. This view faded as people accepted that Earth orbits the Sun. New planets became a possibility, too.

✶ **New worlds** Each following century brought the discovery of a new planet: Uranus, Neptune and Pluto*. By the 20th century, it had become clear that the Solar System is littered with rocky and icy objects such as asteroids and dwarf planets.



Pulsar planets

✶ **Beyond the Sun** In 1992, the first two exoplanets (planets outside our Solar System) were discovered, orbiting a pulsar,† by Polish astronomer Aleksander Wolszczan and Canadian Dale Frail. In 1995, the first planet of a Sun-like star was found: 51 Pegasi b.

† see *Extreme stars* card

Planet discoverers

Uranus: 1781, William Herschel, England

Neptune: 1846, Johann Galle and Louis d'Arrest, Germany

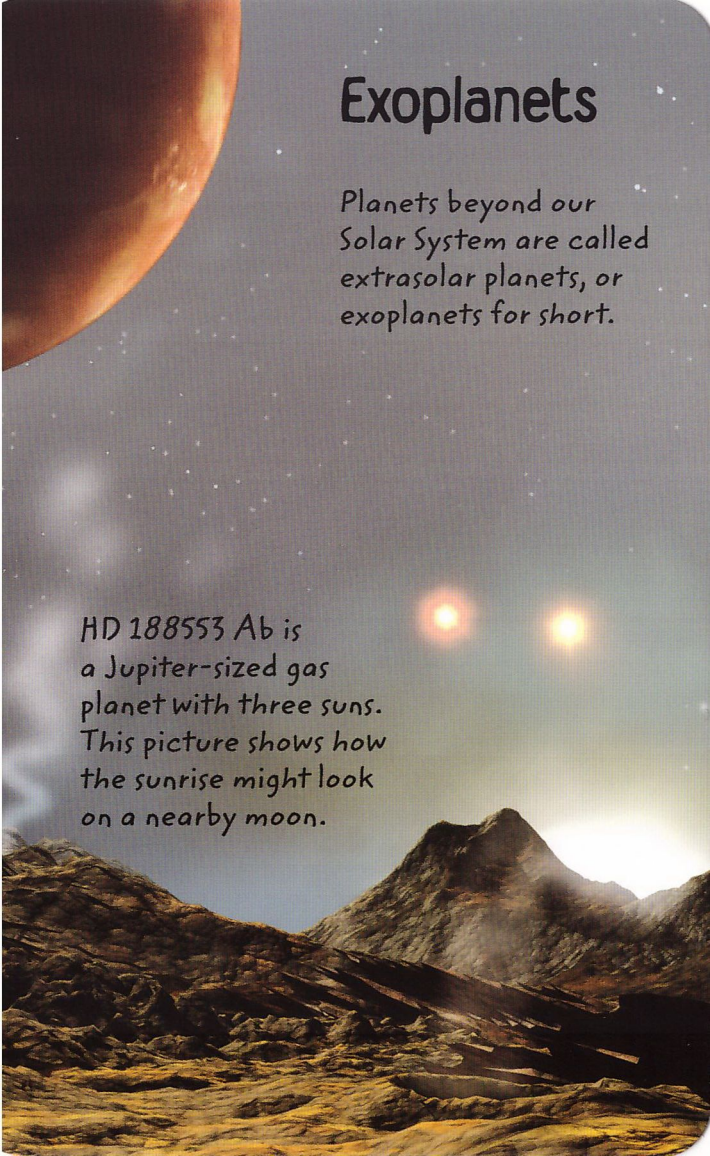
***Pluto:** (now called a dwarf planet) 1930, Clyde Tombaugh, USA

51 Pegasi b: 1995, Michel Mayor and Didier Queloz, Switzerland

Front image: NASA/Kepler mission/Wendy Stenzel; **Back**: NASA/JPL-Caltech/R. Hurt (SSC)

Exoplanets

Planets beyond our Solar System are called extrasolar planets, or exoplanets for short.



HD 188553 Ab is a Jupiter-sized gas planet with three suns. This picture shows how the sunrise might look on a nearby moon.

✶ **Spotting planets** Planets are dim, and hard to spot in the glare of the stars they orbit. But clues such as the slight wobble a planet's gravity causes in its star, or a dip in brightness when it crosses in front, can tell astronomers a planet's size.

✶ **Naming planets** Exoplanets are named after their star plus a small letter. The first found is 'b'. If several are found at the same time, the closest comes first. For example, if Earth were an exoplanet, it would be Sol d. (Sol=the Sun)

✶ **WASP-17b** This hot gas planet, twice the size of Jupiter, is the largest exoplanet discovered so far. It orbits in the opposite direction to the way in which its star turns. A near-miss with another planet may have altered its course.

WASP-17b

✶ **Steam planet** GJ1214b is 2.7 times the size of Earth, and orbits a dim red dwarf star, just 40 light years away in the constellation of Ophiuchus. Its atmosphere is made up of steam as hot as 279 °C (535 °F).

The nearby exoplanet GJ1214b and its star

More exoplanets

51 Pegasi b: the first exoplanet found around a Sun-like star

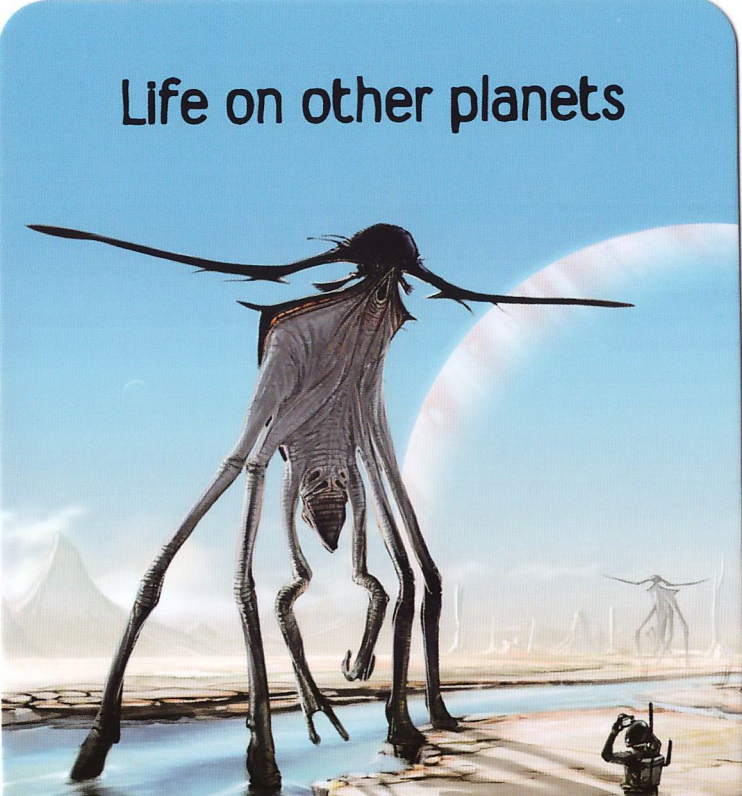
HD 149026 b: a pitch-black planet in Hercules, very close to its star

Kepler-11: a Sun-like star in Cygnus with six planets in close orbit

COROT-7b: a rocky planet in Monoceros, 1.6 times as wide as Earth

Front image: NASA/JPL-Caltech; **Back**: (l) CfA/David Aguilar (r) Ignacio González Tapia/NASA

Life on other planets



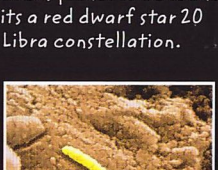
This is a science fiction artist's idea of a truly 'alien' alien, meeting its first human. He imagined that it had evolved from creatures like stingrays.

✶ **Signs of life** To look for alien life, you first need an idea of what life is. All living things on Earth need liquid water, and chemicals such as carbon to survive and grow. A planet where these can exist is a good place to start searching.

✶ **Goldilocks planets** These are Earth-like planets whose distance from their star makes them, like Baby Bear's porridge, neither too hot nor cold, but 'just right' for liquid water and possible alien life.

The first potential Goldilocks planet to be found was Gliese 581d. It orbits a red dwarf star 20 light years away in the Libra constellation.

✶ **ALH84001** This Martian meteorite, found in Antarctica in 1984, contains tiny structures that some scientists think are the fossils of bacteria that used to lived on Mars.



This wormy thing may be a Martian fossil.

✶ **SETI** The Search for Extra-Terrestrial Intelligence scans radio signals from space for signs of alien civilization. One called the 1977 'Wow! signal' has yet to be explained. It came from the star system Chi Sagittarii, but was never heard again...

Alien hunters

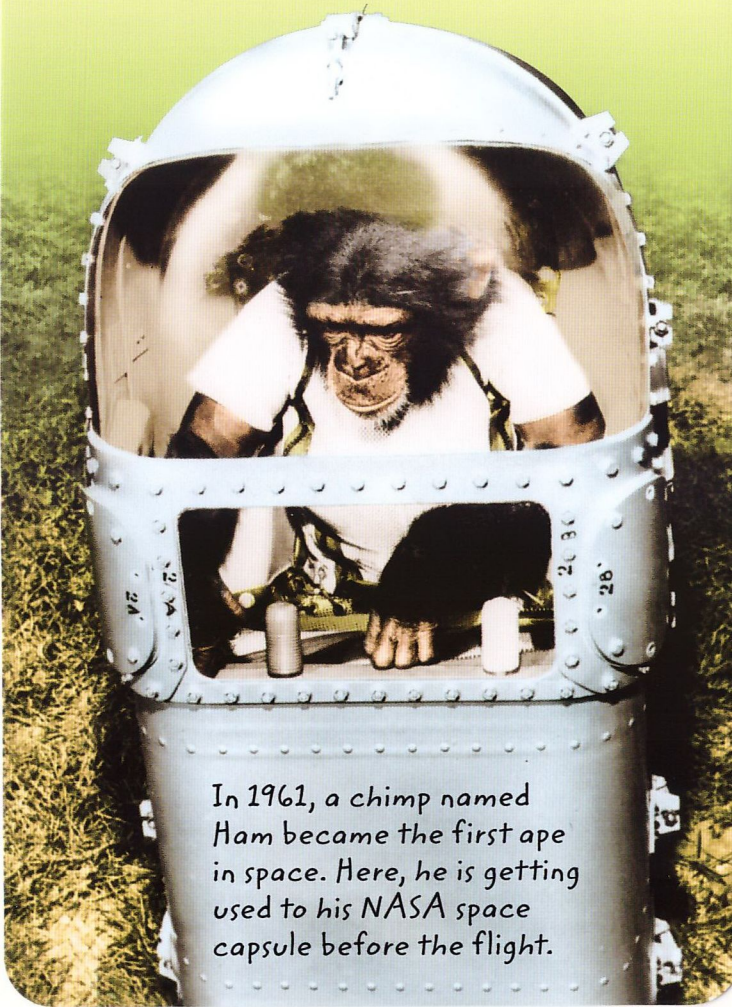
Frank Drake: performed the first SETI search in 1960

Carl Sagan: founded astrobiology, the study of life beyond Earth

Jill Tarter: runs the SETI Institute, searching for aliens in many ways

David McKay: suggested that ALH84001 proves past life on Mars

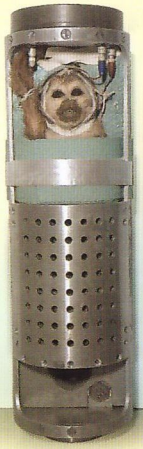
Animal astronauts



In 1961, a chimp named Ham became the first ape in space. Here, he is getting used to his NASA space capsule before the flight.

✶ **Space flies** The very first animals in space were fruit flies aboard an American V2 rocket in 1946. They were safely returned to Earth.

✶ **Albert II** A rhesus monkey, Albert II, was the first mammal in space. In 1949, his V2 rocket reached a height of 134km (83 miles), past the official edge of space at 100km (62 miles) – although NASA says you're an astronaut if you go 80km (50 miles) up.



This is Baker, a squirrel monkey, before NASA's 1959 Jupiter AM-18 mission. She and her crewmate Able were the first monkeys to return alive from space.

✶ **Laika** The first animal to orbit Earth was Laika ('Barker') – a dog on the 1957 Russian spacecraft Sputnik-2. She died from overheating, but proved that animals could survive a rocket launch.

✶ **Astrochimp** Ham the space chimp was trained (using bananas and mild electric shocks) to pull a lever when a light flashed. This was to test whether humans would be able to carry out space missions. Ham performed perfectly and got back safely.

More animal astronauts

1st dogs in space: Dezik and Tsygan, Russia, R-1 rocket, 1951

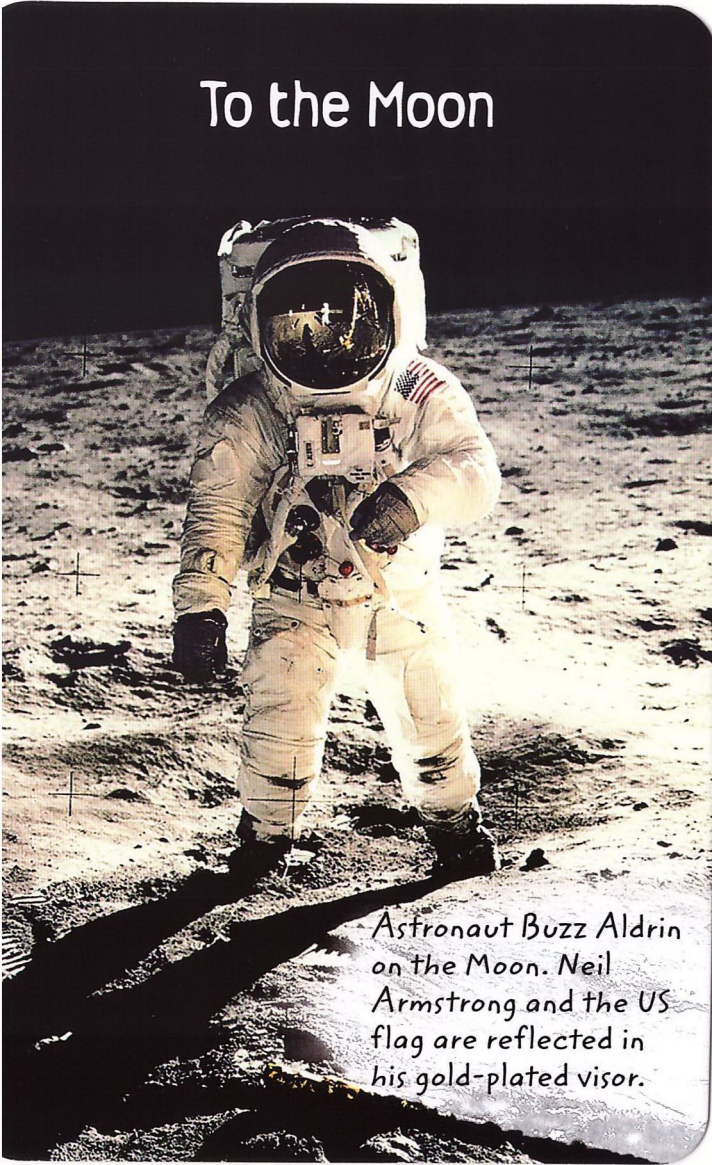
1st cat in space: Félicette, France, Véronique AG147, 1963

1st animals to orbit Moon: turtles and worms, Russia, Zond-5, 1968

1st spiders in space: Arabella and Anita, USA, Skylab 3, 1973

Images: NASA

To the Moon



Astronaut Buzz Aldrin on the Moon. Neil Armstrong and the US flag are reflected in his gold-plated visor.

★ **The Eagle's landing** On July 20, 1969, Apollo 11 astronauts Neil Armstrong and Buzz Aldrin became the first men on the Moon. The Eagle lander overshot its planned landing site, but Armstrong managed to pilot the Eagle across risky terrain to its historic touchdown.

Buzz Aldrin climbs down onto the Moon's surface.

★ **Moon shot** At age 47, Project Mercury astronaut Alan Shepard flew to the Moon on Apollo 14, becoming the oldest moonwalker – and the first man to play golf on the Moon.

Alan Shepard

★ **Be prepared** Eleven of the twelve astronauts who walked on the Moon were former Boy Scouts.

★ **Believe it or not** The maiden name of Buzz Aldrin's mother, Marion, was Moon.

More Moon mission milestones

1959: Luna-2 (Russia) – 1st probe to crash-land on the Moon

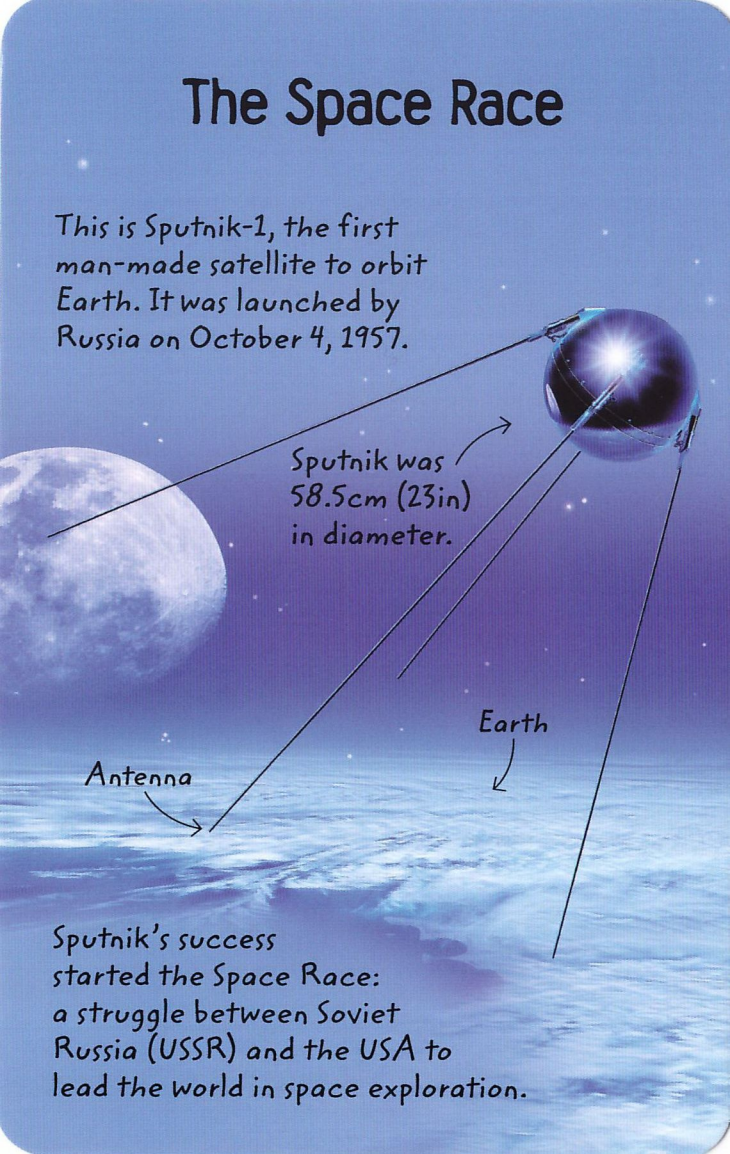
1966: Luna-9 – 1st controlled landing, sent back photographs

1966: Luna-10 – 1st probe to enter the Moon's orbit

1968: Apollo 8 (USA) – 1st manned spacecraft to orbit the Moon

Images: NASA

The Space Race



✶ **NASA** In 1958, less than a year after Sputnik, the USA responded to Russia's challenge by forming the National Aeronautical and Space Administration (NASA).

✶ **First flight** On April 12, 1961, Russian cosmonaut Yuri Gagarin became the first man in space. He orbited the Earth during the space flight Vostok-1.


The Huntsville Times

Man Enters Space

So Close, Yet So Far, Sighs Cape

U.S. Had Hoped For Own Launch

Soviet Officer Orbits Globe In 5-Ton Ship

Maximum Height Reached Reported As 188 Miles

Praise Is Heaped On Major Gagarin

A paper from Huntsville, Alabama, where the Moon rocket was built

✶ **The Mercury 7** 1959's Project Mercury was NASA's first plan for manned spaceflight. To show their unity, all its astronauts gave their spacecraft names ending '7'.

The seven Mercury astronauts

✶ **Freedom 7** In 1961, Mercury astronaut Alan Shepard flew on Freedom 7, becoming the first American in space. He later became one of the Apollo astronauts, who together won the Space Race for the USA by reaching the Moon. (You can find out more on the *To the Moon* card.)

More Space Race milestones

1962: John Glenn – 1st American to orbit Earth (Friendship 7)

1962: Mariner 2 (NASA) – 1st probe to pass another planet (Venus)

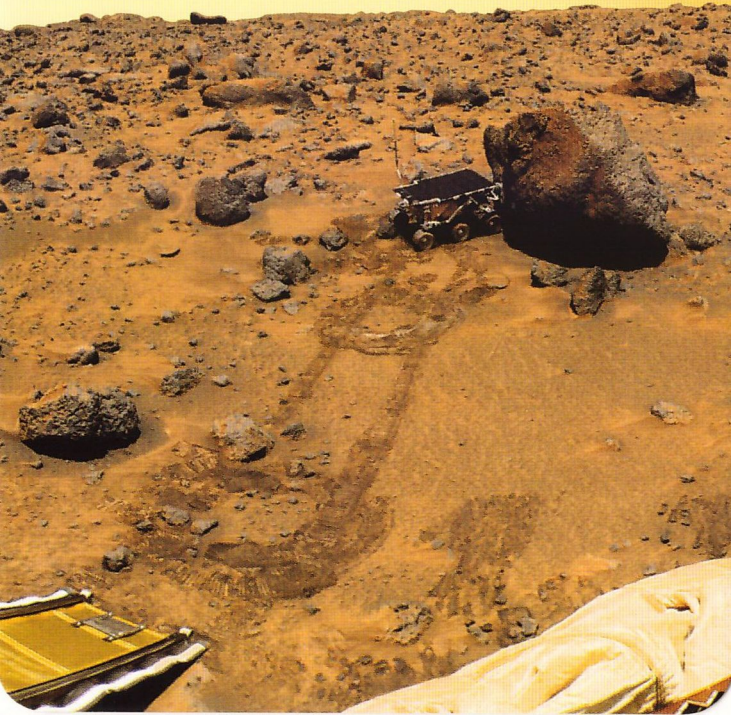
1963: Valentina Tereshkova – 1st woman in space (Vostok-6)

1965: Alexei Leonov (USSR) – 1st spacewalk (Voshkod-2)

Front image: Detlev van Ravenswaay/SPL; **Back**: NASA

Missions to Mars

This is Sojourner, the first robot rover (exploration vehicle) on Mars, in 1997. It is investigating a rock, which its controllers back on Earth nicknamed Yogi after the cartoon bear, because they thought it looked like a bear's head looking away.



✶ **Mariner** NASA's Mariner probes were the first to Mars. Mariner 4 found Mars to be a rocky, desert planet. Mariner 9 discovered the vast canyon Valles Marineris, Latin for Mariner's Valleys.

✶ **Life on Mars** Viking 1 was the first spacecraft to land safely on Mars. It tested soil for signs of life, and seemed to find nothing. Scientists are now less sure that Mars is a dead planet: NASA's 2011 roving Mars Science Laboratory should help to find out.

✶ **Clever devil** The deserts of Mars are swept by whirlwinds called dust devils. In 2006, NASA's Spirit rover was in trouble. Its solar panels, used to recharge its batteries with sunlight, were clogged with dust. A dust devil helpfully blew it all away.

✶ **Going to Mars** When US astronauts went to the Moon, the USA was Russia's rival in the 'Space Race'. Today, America isn't in a rush to reach Mars, but says it could land people there by the 2030s.

Major Mars missions

1964/71: Mariner 4 and 9, USA

1975: Viking 1 and 2, USA

1988: Phobos 1 and 2, Russia

1996: Mars Global Surveyor, USA

1997: Mars Pathfinder, USA

2001: Mars Odyssey, USA

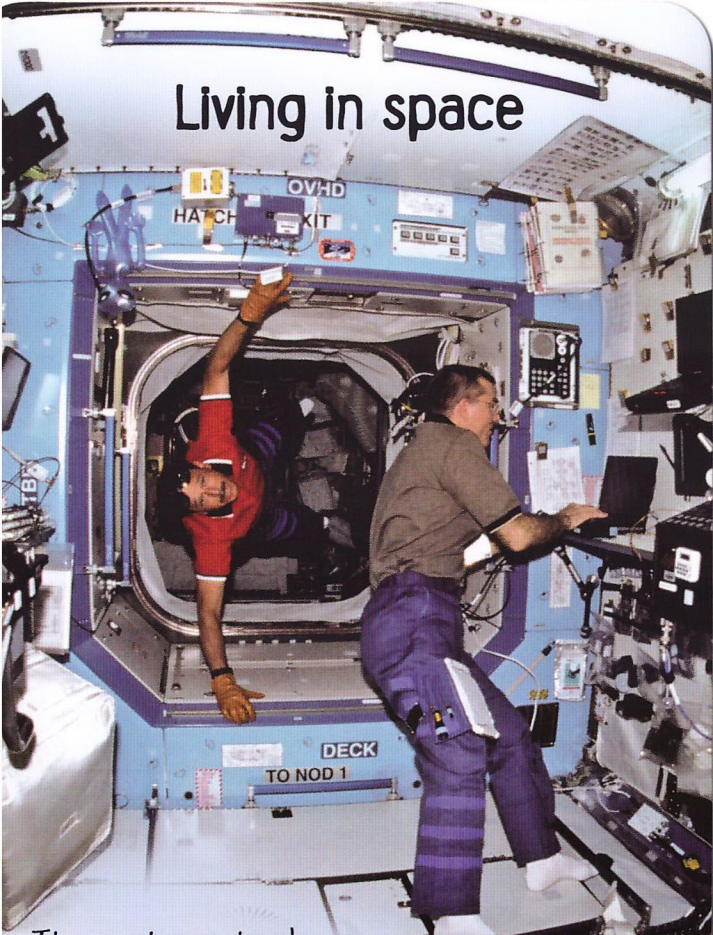
2003: Mars Express, Europe

2006: Mars Recon. Orbiter, USA

2007: Phoenix Mars Lander, USA

Front image: NASA/JPL; **Back**: NASA

Living in space



These astronauts, along with everything inside the International Space Station (ISS), are in orbit, making them weightless. To them, up and down are just the same.

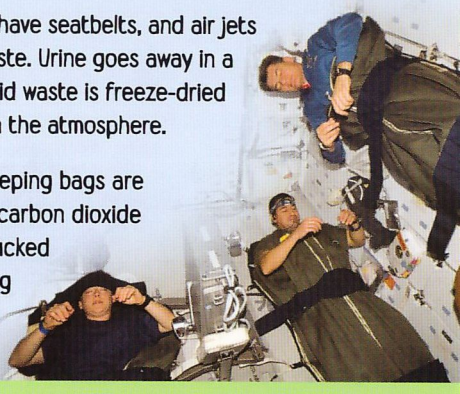
* **Life support** Spacecraft fly oxygen and water to the ISS. This is costly, so water is used sparingly, and all waste water, even urine, is recycled. A life support system makes extra oxygen from water.

* **Eating** Most space food and drink is stored dried. Astronauts add heat and water to make it edible, and use straws so floating drops don't harm electrical equipment. Tortillas don't make crumbs, so they're popular, too.

* **Exercise** Our bodies are used to working against Earth's gravity; without it, bones and muscles start to waste away. ISS astronauts exercise for two hours daily to build their muscles.

* **Space toilets** These have seatbelts, and air jets to flush away solid waste. Urine goes away in a tube for recycling. Solid waste is freeze-dried and later burned up in the atmosphere.

* **Sleep** Astronauts' sleeping bags are tied to the walls. The carbon dioxide they breathe out is sucked away to stop a choking cloud from forming around their heads.



Facts about the ISS

Living and sleeping modules: 2	**Laboratories:** 5
Bathrooms: 2	**Storerooms:** 4
Gyms: 1	**Cost:** $140 billion (estimate)

Living space: 935m^3 (33,023 ft^3) – similar to a Jumbo Jet

Images: NASA

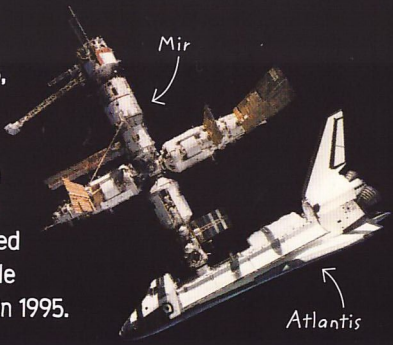
Space stations

This is the International Space Station (ISS), an orbiting science lab manned by astronauts from many countries. It is as long as a football field: the largest man-made object ever built in space.

* **Salyut** The first space station was the Russian Salyut 1, launched into orbit in April 1971.

* **Skylab** This, the first US space station, operated from 1973–1979. Many scientific experiments were performed on board, including studies of the Earth and Sun, and the effects of weightlessness.

* **Mir** This Russian space station, launched in 1986, was the first built up from separate pieces in orbit. By the 1990s, Russia and the USA were working closely in space, symbolized when the US space shuttle *Atlantis* docked with Mir in 1995.



* **Dawn again** As the International Space Station (ISS) hurtles around the Earth, its crew sees the Sun rise every 90 minutes.

* **Science in space** Scientific experiments done on the ISS include studying the effects of low gravity on people, plants and animals. Proteins grown aboard the ISS are already helping scientists to develop new medicines.

International Space Station facts	**Launched:** 1998
Length: 109m (357½ft)	**Countries involved:** 15
Weight: 417 tonnes (460 tons)	**Station crew:** six
Orbits of Earth per day: 15.7	**Ground crews:** 200

Average altitude (height above sea level): 370km (230 miles)

Images: NASA

Astronauts

NASA astronaut Bruce McCandless II during the first spacewalk (movement outside a spacecraft) without a tether, in 1984

✶ **Star sailors** 'Astronaut' comes from the Greek words for 'star sailor'. The Russian word cosmonaut means 'space sailor'.

✶ **Vomit Comet** NASA astronauts train in a plane that flies on a steep path so they enter free fall, and float as they would in space. It makes most trainees feel sick, so it's nicknamed the Vomit Comet.

Astronauts from Japan training in the Vomit Comet

✶ **Suit up** Space is dangerous: it has no air; it can be –160 °C (–256 °F) in the shade, or 120 °C (250 °F) in the sun. Space suits are very thick to protect astronauts from such extremes.

✶ **Blobby** In the weightless conditions of space, liquid forms into floating blobs, making drinking a challenge.

Astronaut studying water in space

✶ **How to be an astronaut** You must be fit and healthy, study hard at science, engineering or mathematics, and get flight training if you want to be a pilot. Learn a language, too: space is international.

Astronaut records

Youngest: Gherman Titov, Russia – flew on Vostok 2, aged 25

1st Chinese astronaut: Yang Liwei – flew on Shenzhou 5, 2003

Longest single spaceflight: Valeri Polyakov, Russia – 437.7 days

Most time spent in space: Sergei Krikalev, Russia – 803.4 days

Images: NASA; With special thanks to Iona Horton

Space robots

This is Robonaut 2, the first human-like robot in space. It boarded the International Space Station in March 2011, to work alongside its astronauts. Robonaut's legs will follow later.

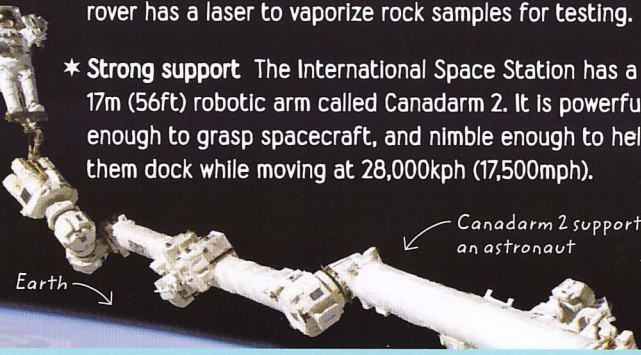
✶ **Lunokhod 1** The first robot to land on the Moon was the Russian rover Lunokhod 1. It landed with the 1970 Luna 17 mission, and took photos and tested soil for 322 days.

✶ **Mars rovers** NASA's Sojourner robot rover went to Mars in 1997. In 2004, the twin rovers Spirit and Opportunity went to study evidence of past water. Spirit outlasted its planned three-month mission, but got stuck in sand in 2010. Opportunity is still going.

Spirit on Mars (artwork)

✶ **Curiosity** NASA's 2011 Mars Science Laboratory, nicknamed Curiosity, is a roving science lab trying to find out if there could ever have been life on Mars. The 3m (10ft) long rover has a laser to vaporize rock samples for testing.

✶ **Strong support** The International Space Station has a 17m (56ft) robotic arm called Canadarm 2. It is powerful enough to grasp spacecraft, and nimble enough to help them dock while moving at 28,000kph (17,500mph).



Space robots in the movies

Forbidden Planet: Robbie the robot

Silent Running: Huey, Louie and Dewie

The Day the Earth Stood Still: Gort

Transformers: Optimus Prime

I, Robot: Sonny

Star Trek: Data; the Borg

Star Wars: R2D2 and C3PO

Terminator: T-800; T-1000

Wall-E: Wall-E and EVE

Front image: NASA; **Back:** (t) NASA (b) CSA

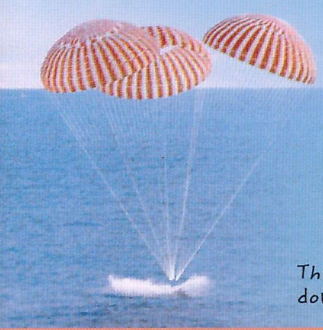
Space disasters

Every astronaut knows that space exploration is risky. In 1986, the Space Shuttle Challenger broke apart shortly after launch, killing all seven of its crew.

✶ **Columbia** Another tragedy for NASA came in 2003, when the Space Shuttle Columbia broke up as it reentered the Earth's atmosphere. Its seven-strong crew was lost.

✶ **Soyuz 11** Most 'space' accidents happen in Earth's atmosphere, but in 1971, the three cosmonauts of Russia's Soyuz 11 died in space when a ventilation valve failed, and their capsule lost pressure.

✶ **Long March 3B** In 1996, this Chinese rocket veered off course and crashed into a nearby village. The official death toll was 56, but it's possible that more than 200 people died.



✶ **Lucky 13** In the 1970 Apollo 13 Moon mission, an oxygen tank exploded, causing a serious electrical fault. Quick thinking by astronauts and ground crew let the lunar module be used as a lifeboat back to Earth.

The crew of Apollo 13 splashing down safely in the Pacific Ocean

Causes of space accidents

Challenger: A broken seal released hot gas from the rocket motor.

Columbia: A piece of protective foam broke off the fuel tank.

Long March 3B: An engineering defect in the rocket

N1 5L: A loose bolt in its fuel pump destroyed Russia's Moon rocket.

Images: NASA

Spacecraft

This is the Space Shuttle Atlantis being launched in 1989. Inside it was the space probe Magellan, which was on its way to Venus.

✶ **Luna-1** Space probes are unmanned, robotic spacecraft that leave Earth's orbit. The first was Russia's Luna-1, in 1959. It missed its target (the Moon) but became the first man-made object to orbit the Sun.

✶ **Swallow** The first manned spaceflight, Vostok-1, was in a Russian spacecraft. Yuri Gagarin was chosen to pilot Lastochka ('swallow') partly because he was short enough to fit into its cramped cockpit.

✶ **Voyager 1** Launched in 1977, the Voyager 1 probe is now at the edge of the Solar System. At 17 billion km (11 billion miles) away, it is the most distant man-made object from Earth.

✶ **Shuttle service** Between 1981 and 2011, NASA had a fleet of five Space Shuttles. These reusable space planes ferried astronauts to and from space stations, and launched other spacecraft.

✶ **Soyuz** Russia's Soyuz TMA spacecraft are now the only way for astronauts to reach the International Space Station. At least one is always docked there as a 'lifeboat' in case of emergencies.

Spacecraft facts

Fastest: Helios, USA/Germany, 1976 – 252,792kph (157,078mph)

Visited most planets: Voyager 2, USA – four planets

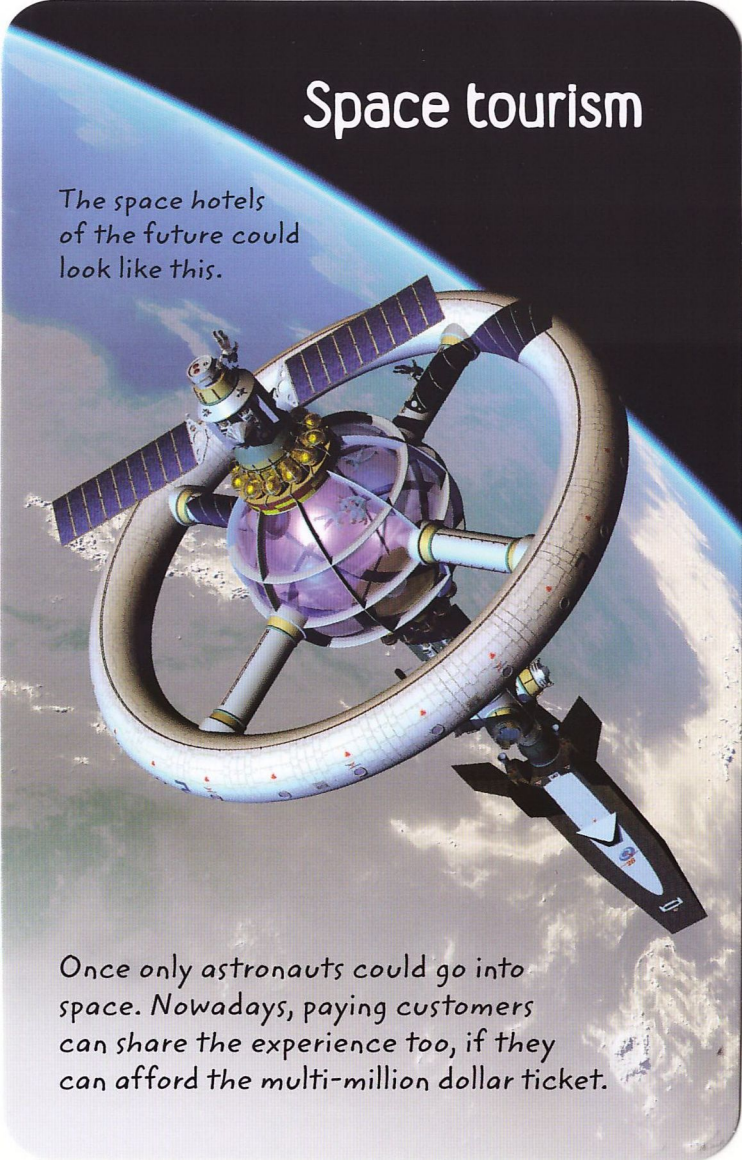
Most reliable rockets: Russian Soyuz rockets are used most often

Biggest rocket: Saturn V, USA, 111m (363ft); 3,039 tonnes (3,350 tons)

Front image: NASA; **Back**: (t) Detlev van Ravenswaay/SPL (b) NASA

Space tourism

The space hotels of the future could look like this.



Once only astronauts could go into space. Nowadays, paying customers can share the experience too, if they can afford the multi-million dollar ticket.

✶ **Tito** In 2001, private spaceflight company Space Adventures arranged for a US businessman named Dennis Tito to visit the International Space Station on a Russian Soyuz spacecraft, making him the first space tourist. It cost him $20 million.

✶ **The X-Prize** The Ansari X-Prize was a competition launched in 1996 that offered a $10 million prize for the first successful private spaceflight.

✶ **SpaceShipOne** On June 21 2004, SpaceShipOne, designed by Burt Rutan, and piloted by Mike Melvill, became the first private vehicle to enter space, and later won the X-Prize.

✶ **Virgin Galactic** This company is working with Burt Rutan's firm Scaled Composites to fly paying clients on their new SpaceShipTwo. Passengers will experience stunning views of Earth, and weightlessness.

✶ **Space hotels** The firm Bigelow Aerospace plans to build inflatable space hotels. Genesis II is a test version, in orbit since 2007. The first Bigelow space hotel could be ready by 2015.

Private spaceflight companies

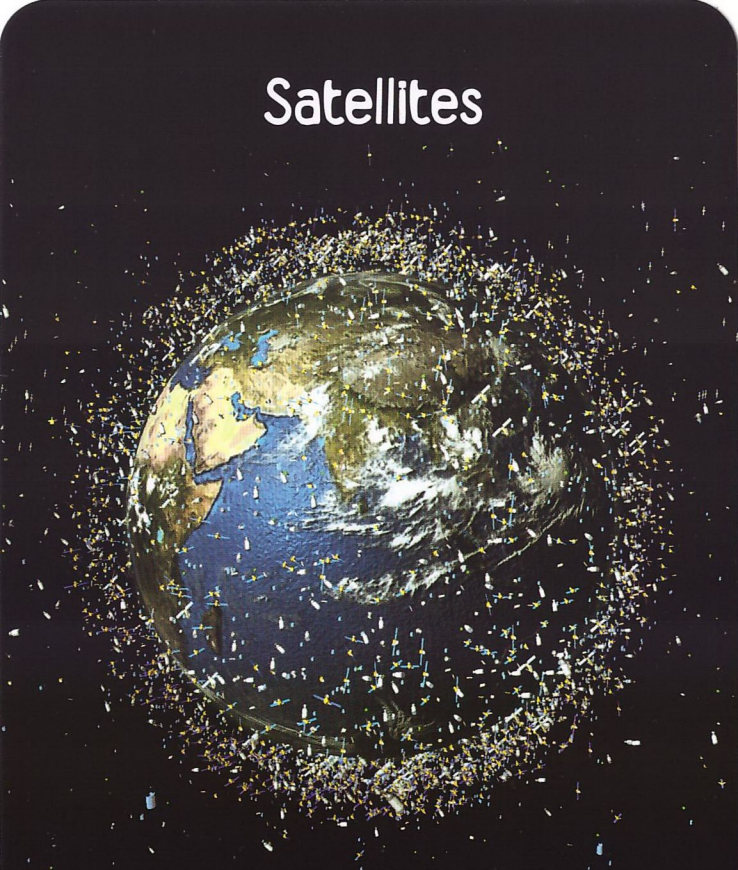
SpaceX: 1st private rocket (Falcon) and spacecraft (Dragon) firm

Space Adventures: plans to fly tourists around the Moon by 2015

The Spaceship Company: Virgin and Burt Rutan's joint venture

Blue Origin: building a reusable rocket called New Shepard

Satellites



A satellite is anything that orbits something else. The Earth has just one natural satellite (the Moon) but nearly 16,000 man-made satellites, working and retired, move around it. Their size in this picture is exaggerated.

High

Medium

Outer Van Allen Belt (V.A.B.)

Inner V.A.B.

Low

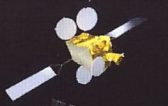
★ **High fliers** Satellites with different jobs orbit at different heights. Most are in Low Earth Orbit, 160–2,000km (100–1,240 miles) up. This is because it's costly to send them higher, but it also avoids the Van Allen Radiation Belts, which damage unshielded satellites.

Geostationary
Orbit: 35,786km (22,236 miles)

Uses: TV, weather, communications

Global Positioning System (GPS)
Orbit: 20,350km (12,645 miles)

Uses: accurately pinpointing any spot on Earth



Polar Orbiting
Orbit: 1,700km (1,056 miles)

Uses: mapping and photographing the Earth

International Space Station (ISS)
Orbit: 370km (230 miles)

Uses: scientific experiments, observing the Earth

★ **Space junk alert** Thousands of old satellites orbit Earth at such high speed that broken-off pieces can punch holes in working models. The ISS is shielded from small debris, but has to dodge big pieces of junk every year.

Satellite facts

*In January 2011

Satellites orbiting Earth*: 15,899 (3,380 working + 12,519 dead)

1st satellite: Sputnik-1, Russia, 1957

1st communications satellite: Project SCORE, USA, 1958

1st satellite crash: Iridium 33 (USA) hit Cosmos 2251 (Russia) in 2009

Front image: NASA; **Back**: (l) NASA Earth Observatory (r1) NASA/NOAA-19 (r2) USAF/Navstar (r3) ©EADS Astrium (r4) NASA